SOCIETAS GEOGRAPHICA FENNIAE

ACTA GEOGRAPHICA

4

HELSINKI — HELSINGFORS

1932

Henrik Renqvist

SOCIETAS GEOGRAPHICA FENNIAE

ACTA GEOGRAPHICA

4

HELSINKI — HELSINGFORS

1932

HELSINKI — HELSINGFORS

1932

SUOMALAISEN KIRJALLISUUDEN SEURAN KIRJAPAINON OY.

ACTA GEOGRAPHICA

4

1 Map; 33 Plates; 33 Figures in the Text; Text 242 Pages.

ACTA GEOGRAPHICA 4, N:o 1

WEITERER BEITRAG ZUR KRANIOLOGIE DER FEUERLÄNDER

VON

KAARLO HILDÉN

MIT EINER TAFEL

HELSINKI—HELSINGFORS 1931

HELSINKI 1931
SUOMALAISEN KIRJALLISUUDEN SEURAN KIRJAPAINON OY.

Im Herbst 1930 veröffentlichte ich eine Untersuchung über zwei Indianerschädel, welche die von der Geographischen Gesellschaft Finnlands nach dem Feuerland ausgesandte Expedition mitgebracht hatte.[1] Nach dem Erscheinen dieser Abhandlung erhielt ich von meinem Freunde Mag. phil. Åke Laurin die Mitteilung, dass ein feuerländischer Schädel in den Sammlungen der Gemeinschule in Grankulla in der Nähe von Helsinki aufbewahrt werde. Da bekanntlich das kraniologische Material für die aussterbenden Indianerstämme in Feuerland sehr gering ist, dürfte es angebracht sein eine kurze Mitteilung auch über diesen Schädel zu veröffentlichen und zwar um so mehr, als Prof. M. Gusinde in einer Besprechung (Anthr. Anzeiger VII, 1931, S. 186) »erneut die dringliche Bitte» ausspricht, dass für eine von ihm und Dr. Lebzelter vorbereitete Monographie über die Feuerländer »die in verschiedenen Sammlungen vorhandenen Stücke . . . baldigst veröffentlicht werden möchten». Ich gehe hier indessen nicht auf einen eingehenderen Vergleich mit früher erhaltenen Ergebnissen ein, da ich in diesem Falle manches aus meiner früheren Abhandlung wiederholen müsste, sondern begnüge mich damit die wichtigsten Masse und deskriptiven Merkmale mitzuteilen.[2]

Der Schädel war schon durch verschiedene Hände gegangen, bevor er nach Grankulla gelangte. Der Bruder eines der Lehrer der dortigen Gemeinschule erwarb ihn vor einer Reihe von Jahren in Ultima Esperanza von einem Ansiedler, der ihn seinerseits in dem feuerländischen Archipelag erhalten (oder ausgegraben) hatte. Genauere Angaben über den Fundort fehlen leider, so dass sich nicht mit Bestimmtheit angeben lässt, ob der Schädel einem Yahgan oder einem Alakaluf gehört hat — beide Stämme bewohnen ja den feuerländischen Archipelag, den »Archipiélago de Magallanes», die ersteren die Gegenden um den

---

[1] Kaarlo Hildén: Zwei Indianerschädel aus Feuerland. Acta Geographica 3, N:o 2. 48 Seiten und 2 Tafeln. Helsinki 1930. — Die beiden Schädel werden jetzt im Anatomischen Institut der Universität aufbewahrt.

[2] Ich erwähne in der vorliegenden Mitteilung nur einige vergleichende Angaben, die sämtlich der folgenden Arbeit entnommen sind:

Martin Gusinde: Zur Kraneologie der Feuerländer. Atti del XXII Congresso internazionale degli Americanisti. Vol. I. Ss. 337—356. Roma 1928.

Beaglekanal und die Inseln südlich und südwestlich von diesem, die letzteren das westliche Inselgebiet von der Brecknock-Halbinsel im Süden bis nordwärts an die Ausgänge zum Golfo de Peñas. Da sich diese beiden Stämme in ihrem Körperbau — wie auch in ihren Sitten — sehr ähneln, dürfte sich die Stammeszugehörigkeit auf Grund einer kraniologischen Analyse nicht entscheiden lassen. Wir müssen uns also mit der Feststellung begnügen, dass der Schädel von den sogen. Kanalindianern, den »indios canoeros» stammt.

Der Schädel — oder genauer das Calvarium, denn der Unterkiefer fehlt — ist nicht vollständig erhalten. Das Schädeldach weist auf der rechten Seite ein grosses Loch auf, das einen grossen Teil des Parietale und einen kleineren Teil des Frontale umfasst, und dadurch entstanden zu sein scheint, dass der Schädel teilweise über dem Erdboden gelegen hat und an diesen Stellen vermodert ist. Sonst ist er ziemlich gut erhalten — nur die Zähne fehlen bis auf 4 Molaren, und hie und da finden sich besonders in der Nasen- und Orbitalregion sowie im basalen Teil des Schädels einige kleinere Knochenbrüche, die jedoch keine Bedeutung für eine anthropologische Untersuchung haben.

In seinem allgemeinen Aussehen erinnert der Schädel, der etwas asymetrisch ist, ziemlich stark an den von mir früher untersuchten Yahganschädel, wenn er auch durchaus keine getreue Kopie desselben darstellt.

In der Norma verticalis ist der Schädel ausgeprägt langgestreckt. Da die grösste Breite ziemlich weit nach hinten liegt und die Stirn sich nach vorn stark verschmälert, macht der Schädel einen eiförmigen Eindruck, weshalb er nach der SERGIschen Terminologie als Ovoides zu bezeichnen ist. Hinter den stark gewölbten Scheitelhöckern tritt das Hinterhaupt nur mässig hervor. Nach vorn wird das Schädeldach durch die kräftig entwickelten Überaugenwülste begrenzt. Auch die Jochbogen sind deutlich erkennbar, so dass der Schädel als phaenozyg zu bezeichnen ist. — In der Norma lateralis macht der Schädel im ganzen einen niedrigen Eindruck. Deutlich treten nach vorn zu die mächtigen Augenbrauenbogen hervor. Hinter diesen fällt die gewölbte Stirn stark nach hinten ab und geht ohne Knickung in die Parietalkurve über. Diese verläuft in ziemlich regelmässiger Krümmung bis zum Inion weiter, worauf ein hervortretender mächtiger Torus occipitalis folgt. — In der Norma frontalis tritt die für feuerländische Schädel typische Dachform, die Lophokephalie, deutlich hervor. Auch fällt die schmale Stirn, deren Schmalheit noch durch die seitwärts vorspringenden, wulstigen Trigona supraorbitalia hervorgehoben wird, in die Augen. Die Orbitae sind mittelgross und abgerundet viereckig. Die Jochbogen sind mittelstark gebaut und geben

zusammen mit den Wulstigkeiten der Supraorbitalregion dem ganzen Gesicht einen eckigen Eindruck. — In der Norma occipitalis macht sich vor allem die ausgesprochene Dachform geltend. Das Aussenrelief wird durch den oben genannten starken Torus occipitalis charakterisiert. Ich verweise im übrigen auf die Abbildungen.

Das Gewicht des Calvariums lässt sich infolge der starken Beschädigung auf der rechten Seite nicht mit Bestimmheit angeben. Schätzungsweise beträgt es 750 gr, also ein ziemlich hoher Wert.

Die Schädelkapazität (mit Hirsekron gemessen) beträgt 1400 ccm, so dass der Schädel nach der üblichen Einteilung als euenkephal bezeichnet werden kann.

Die allgemeinen Grössen- und Formverhältnisse gehen aus der folgenden Zusammenstellung hervor:

Grösste Hirnschädellänge von der Glabella aus	188 mm
» » vom Nasion aus	183 »
Glabella-Inion-Länge	183 »
Nasion-Inion-Länge	177 »
Glabella-Lambda-Länge	182 »
Nasion-Lambda-Länge	180 »
Schädelbasislänge (Nasion-Basion)	99 »
Nasion-Opisthion-Länge	133 »
Grösste Euryenbreite	138 »
Breite zw. Cristae supramast.	135 »
Basion-Bregma-Höhe	131 »
Opisthion-Bregma-Höhe	145 »
Ohrhöhe (zum Bregma)	111 »

Die Masse ergeben folgende allgemeine Indices:

Längenbreiten-Index	73.4
Längenhöhen-Index	69.7
Breitenhöhen-Index	94.9
Längen-Ohrhöhen-Index	59.0
Breiten-Ohrhöhen-Index	80.4

Der Schädel ist mithin dolichokran (L.Br.-I.), chamaekran (L.-H.-I.) ganz an der Grenze der Orthokranie, metriokran (Br.-H.-I.), orthokran (L.-Ohrh.-I.) und metriokran (Br.-Ohrh.-I.).

Sowohl die absoluten Masse wie die Indices stimmen gut mit den entsprechenden Massen und Indices von früher untersuchten normalen feuerländischen Schädeln überein, und zwar besonders mit solchen von männlichen Yahgans und Alakalufs.

Die folgenden Masse der Umfänge und Bogen seien hier mitgeteilt:

Horizontalumfang über die Glabella	528 mm		
» » das Ophryon	515 »		
Transversalbogen (über Bregma)	311 »		
Mediansagittalbogen	378 »		
davon Frontalbogen	127 »	oder	33.6 %
» Parietalbogen	127 »	»	33.6 »
» Occipitalbogen	124 »	»	32.8 »

Die Umfänge und Bogen, durch welche bekanntlich die absolute Grösse des Gehirnschädels am besten festgestellt wird, zeigen, dass wir es mit einem grossen Schädel zu tun haben. In dieser Beziehung stimmt unser Schädel mit früher untersuchten feuerländischen Schädeln überein, die — besonders für den Horizontalumfang — ungewöhnlich grosse Masse zeigen.

Eine gewisse Beachtung verdient das Längenverhältnis zwischen den drei Deckknochen im Mediansagittalbogen. Wir finden, dass Frontal- und Parietalbogen gleich lang sind und dass wie innerhalb der Primatenreihe der Occipitalbogen den kürzesten Abschnitt bildet. Ein ähnliches Verhältnis ist jedoch auch früher schon bei den feuerländischen Schädeln festgestellt worden. Der sagittale Frontooccipital-Index ist 97.6, der Frontoparietal-Index 100.0.

Ich behandele im folgenden kurz die einzelnen Regionen des Schädels.

Frontale. Die Stirnbeinschuppe ist schmal, stark nach hinten fliehend, aber gleichzeitig regelmässig gewölbt. Die kleinste Stirnbreite beträgt 93.5 mm, die grösste (Breite der Coronalnaht) 118 mm. Der transversale Frontal-Index ist somit 79.2, der transversale Frontoparietal-Index 67.8. Der Schädel ist mithin metriometop, bzw. mesosem.

Der Stirnneigungswinkel (Bregma-Nasion-Inion) ist etwa 50°, ein Wert, der als sehr niedrig zu bezeichnen ist und der zeigt, dass das Bregma weit nach hinten liegt. Das Frontale ist aber wie gesagt ziemlich kräftig gewölbt. Da die Frontalsehne 111 mm und der Frontalbogen 127 mm ist, so ergibt sich ein sagittaler Frontal-Index von 87.4, ein Wert der dem von Gusinde erhaltenen nahe kommt. Die Wölbung ist fast ebenso stark im glabellaren wie im cerebralen Teil. Der Krümmungs-Index der Pars glabellaris beträgt 91.7, während der entsprechende Index der Pars cerebralis 92.2 ist. Beide Werte sind für feuerländische Verhältnisse verhältnismässig niedrig.

Die Stirnhöcker sind sehr schwach entwickelt. Dagegen ist ein deutlicher, wenn auch flacher Torus sagittalis vorhanden, der jedoch nicht, wie häufig bei feuerländischen Schädeln der Fall ist, in eine deutliche Wulstung der Breg-

maregion übergeht. Die Lineae temporales sind als leistenartige Erhebungen ausgeprägt, die Schläfen selbst eingesunken.

Stark hervortretend ist die Supraorbitalregion, die einen australoiden Charakter zeigt. Die beiderseitigen kräftigen Arcus superciliares sind in einer vorgewölbten Glabella miteinander vereinigt und in ihren medialen Partien dermassen tief herabgerückt, dass sie mit dem Orbitalsaum verschmelzen. Sehr kräftig gewulstet sind auch die Trigona supraorbitalia, welche jedoch nicht mit den Arcus verschmolzen sind, sondern von diesen durch deutliche, obschon seichte Rinnen getrennt sind. Diese Ausbildung der Supraorbitalregion entspricht etwa der zweiten Form des Gunningham-Schwalbeschen Schemas, die ja unter den rezenten Hominiden besonders häufig bei den Australiern vorkommt.

Der Nasenfortsatz des Stirnbeins ist lang und breit, was als eine primitive Bildung aufgefasst wird.

P a r i e t a l e. Die Tubera parietalia sind sehr deutlich ausgeprägt. Unterhalb dieser Höcker fallen die Parietalia fast senkrecht ab, während sie oberhalb der Tubera stark abgeflachte, sogar etwas vertiefte Flächen bilden, die sich gegen die hochliegende Sutura sagittalis, deren Rand schwach gewulstet ist, dachförmig erheben. Das Schädelgewölbe erhält hierdurch eine ausgesprochene Hausform, die ja für feuerländische wie für australische Schädel typisch ist. Die Schläfenlinien sind sehr schwach ausgebildet. Zwei winzige Parietallöcher sind vorhanden.

Die absoluten Masse und Sehnenbogen-Indices sind folgende:

Sagitt.	Parietalbogen	127	mm.	Sagitt.	Parietalsehne	114	mm.	Sagitt.	Wölb.-I.	89.8
Front.	»	103	»	Front.	»	92	»	Front.	» »	89.3
Temp.	»	102	»	Temp.	»	98	»	Temp.	» »	96.1
Occip.	»	97	»	Occip.	»	87	»	Occip.	» »	89.7

Die Ränder des Scheitelbeins sind also, mit Ausnahme des Margo temporalis, ziemlich stark gewölbt. Ein eigentümlicher Zufall ist es, dass fast alle meine Wölbungsindices bis auf einigen Dezimalen mit den Mittelwerten übereinstimmen, die Gusinde für die von ihm untersuchten männlichen Yahganschädel anführt.

T e m p o r a l e. Die Schläfenschuppe ist ziemlich klein und hat eine langgestreckte Form. Der obere Rand ist nur schwach gewölbt und verläuft, besonders auf der rechten Seite, annähernd geradlinig, wie beim Australier häufig der Fall ist. Das Aussenrelief wird vor allem durch die kammartig vorspringende Crista supramastoidea charakterisiert, die nach hinten über die Sutura squamosa sich fortsetzt. Vor der Naht ist die Crista zu einem breiten, wulsti-

gen Tuberculum supramastoideum entwickelt. Unter der Crista liegt ein sehr deutlicher breiter Sulcus supramastoideus, der zum Scheitelbein hinaufzieht. Die Processus zygomatici sind recht kräftig entwickelt. Da die Schläfen eng sind, ist der Schädel, wie früher schon erwähnt wurde, p h a e n o z y g, was als ein primitives Merkmal aufgefasst wird. Die Breite zwischen den Cristae ist relativ sehr gross, 135 mm, also beinahe so gross wie die Euryenbreite, ein Verhältnis, das bei den feuerländischen Schädeln häufig beobachtet worden ist. Der Cristalbreiten-Index beträgt 97.8. Die Schädelkapsel zeigt somit einen senkrechten Aufbau. — Die Sutura sphaenoparietalis ist 8 mm.

Der Porus acusticus externus hat die Form einer schräg nach hinten gerichteten Ellipse. Eine Spina supra meatum ist beiderseits vorhanden. — Die Fossa mandibularis ist tief und breit. Die Processus mastoidei sind mässig.Die Mastoidealbreite ist 101 mm, die grösste Mastoidealbreite 124 mm.

O c c i p i t a l e. Die Aussenfläche der Hinterhauptschuppe ist vor allem durch einen sehr mächtigen, etwa 15—17 mm breiten Torus occipitalis gekennzeichnet, eine Bildung, die unter rezenten Gruppen ja besonders typisch für Feuerländer wie auch für Australier und Ozeanier ist. Sowohl die untere als die obere Grenze des Torus ist scharf markiert. Wo die scharfe, wenig einheitliche Crista occipitalis externa mit der Linea nuchae superior zusammentrifft, liegt die Protuberantia occipitalis externa als rauhe Erhabenheit. An dieser Stelle ist die Hinterhauptschuppe scharf abgeknickt.

Die Wölbungsverhältnisse gehen aus folgenden Massen hervor:

Occipitalbogen	124 mm.	Occipitalsehne	101 mm.	Krümmungs-I.	81.5
Oberschuppenbogen ..	68 »	Oberschuppensehne ..	64 »	»	» 94.1
Unterschuppenbogen ..	56 »	Unterschuppensehne	55 »	»	» 98.2

Das Occipitale ist also im ganzen ziemlich stark gewölbt, während die beiden Abschnitte, besonders die Unterschuppe, nur eine schwache Wölbung zeigen. Obschon die Unterschuppe kürzer ist als die Oberschuppe, ist sie jedenfalls als relativ sehr lang zu bezeichnen, was als ein Zeichen primitiver Formbildung angesehen worden ist. Der Sehnenindex des Occipitale ist 85.9, also ein sehr hoher Wert. Der Occipitalindex, der einigermassen die Lage des Inion innerhalb der Hinterhauptschuppe angibt, ist 80.9. Die Asterienbreite ist 110 mm, der Breitenhöhen-Index des Occipitale 91.8.

Das Hinterhauptloch, dessen hinterer Rand gewulstet ist, ist seiner Form nach etwa rhombisch. Die Länge (35 mm) und die Breite (30 mm) ergeben einen Index von 85.7. Besonders sei hervorgehoben, dass die Achse des Foramen deutlich nach rückwärts aufgerichtet ist, ein primitives Verhalten, das eine

häufige Erscheinung bei feuerländischen Schädeln ist. — Die Condyli occipitales sind hoch, lang und sehr stark gewölbt.

Die Pars basilaris, deren Aussenrelief uneben ist, hat eine Breite von 22 mm. Die Nasion-Hormion-Länge beträgt 28 mm, die Basion-Sphenobasion-Länge 21 mm.

Gesichtsschädel. Die wichtigsten allgemeinen Masse gehen aus folgender Zusammenstellung hervor:

(Nasion-Basion-Länge	99 mm)
Gesichtslänge (Basion-Prosthion)	96 »
Wahre Gesichtslänge (Sphenobasion-Prosthion)	84 »
Obere Gesichtslänge (Sphenobasion-Nasion)	78 »
Seitliche Gesichtslänge (Ektokonchion-Porion	69 »
Nasion-Hormion-Länge	71 »
(Kleinste Stirnbreite	93.5 »)
Postorbitale Breite	94 »
Obergesichtsbreite	105.5 »
Obere Zygomaxillarbreite	55 »
Untere » (Mittelgesichtsbreite)	96 »
Biorbitalbreite	99 »
Jochbogenbreite	134 »
Obergesichtshöhe (Nasion-Prosthion)	70 »

Die absoluten Masse zeigen, dass der Gesichtsschädel in allen Dimensionen als für feuerländische Verhältnisse ziemlich klein zu bezeichnen ist. Immerhin fallen alle Masse in den Bereich der von GUSINDE für männliche Yahgans beobachteten Grenzen.

Auf Grund der absoluten Masse erhält man folgende Indices:

Obergesichtsindex	52.2
Jugofrontal-Index	69.8
Jugomalar-Index	71.6
Frontobiorbital-Index	94.4
Transversaler Craniofacial-Index	97.1

Der Schädel hat ein mittelhohes Obergesicht, er ist mesen, was wohl als typisch für Feuerländer anzusehen ist. Das Verhalten der kleinsten Stirnbreite zur Obergesichts-, Biorbital- und Jochbogenbreite zeigt, dass auf eine schmale Stirn eine relativ breite Ausladung des Gesichts folgt. Die Indices stimmen recht gut mit den Befunden GUSINDES überein. Der transversale Craniofacial-Index ist sehr gross; die Jochbogenbreite und die grösste Schädelbreite sind beinahe gleichgross — ein primitives Verhalten, das für feuerlän-

dische Schädel charakteristisch ist. Der Stirnfortsatz des Jochbeins besitzt einen kräftigen Processus marginalis. Die Wangenbeinhöhe beträgt 23 mm.

Der Ganzprofilwinkel beträgt 84°, der nasale Profilwinkel 88°, der alveolare Profilwinkel 74°. Der Gesichtsschädel ist im ganzen mithin m e s o g n a t h, die Nasenpartie orthognath, die alveolare Partie prognath.

Die Orbitae sind ziemlich gross, abgerundet viereckig. Die Breite (43 mm) und die Höhe (35 mm) ergeben einen Index von 81.4. Der Schädel ist somit m e s o k o n c h. Die Orbitaleingangsebene hat einen grossen frontalen Neigungswinkel. Die vordere Interobitalbreite beträgt 18 mm.

Die Nasenwurzel ist ziemlich breit, doch macht die ganze Nasenregion einen ausgesprochen langgestreckten Eindruck. Die Nasenhöhe beträgt 54 mm, während die Breite nur 21.5 mm ist. Der Nasalindex ist somit nur 38.0, der Schädel stark l e p t o r r h i n. Ein solcher niedriger Nasalindex dürfte bei den Feuerländern nicht früher beobachtet worden. Die beiden Nasalia sind stark asymetrisch, das linke ist schmal, das rechte doppelt breiter. Die Wurzelbreite der Nasalia ist 12.5 mm, die kleinste Breite 7 mm, die grösste 14.5 mm, welche Werte gut mit früheren Befunden übereinstimmen. Die Spina nasalis anterior entspricht etwa der Form 2 des Brocaschen Schemas.

Die Maxillarregion ist mässig kräftig gebaut. Die Maxilloalveolarlänge ist 54 mm, die Breite 61.5 mm, der Index somit 113.9. Die Gaumenlänge, 48 mm, und die (mittlere) Breite, 38 mm, ergeben einen Gaumen-Index von 79.2. Unser Schädel ist demnach m e s u r a n i s c h und l e p t o s t a p h y l i n. Die Gaumen-Endbreite ist 41.5 mm. Die Fossa canina ist, besonders links, sehr deutlich entwickelt. Die Form des Zahnbogens ist paraboloid, obschon die Seitenränder nicht stark nach hinten divergieren. Das Gaumendach zeigt eine unregelmässige, rauhe Oberfläche. Die Spinae palatinae sind stark gefaltet, ein kräftiger Torus palatinus ist vorhanden. Die Sutura palatina transversa ist vollständig obliteriert. Die Spina nadalis posterior ist 5 mm lang.

Die Zähne — nur 4, die ersten und zweiten Molaren sind vorhanden — sind sehr stark abgenutzt, weshalb sie von der Seite gesehen wie abgeschnitten aussehen.

Zusammenfassend können wir sagen, dass der untersuchte Schädel den feuerländischen Schädeln, die früher beschrieben und abgebildet sind, im grossen und ganzen gleicht und zwar sowohl in den Massen — die im allgemeinen sehr gut mit den Massen für Yahganindianer-Schädel übereinstimmen — wie in den deskriptiven Merkmalen. Besonders sei hervorgehoben, dass auch dieser Schädel eine ganze Reihe primitiver Merkmale aufweist, sowohl im

Neuro- wie im Splanchnokranium, die auf weit zurückliegende Verbindungen zwischen der Bevölkerung des Feuerlandes und der austromelanesischen Inselwelt hindeuten. Unsere kraniologische Analyse scheint also die Richtigkeit der Schlussfolgerungen betreffend die Herkunft der inferioren Züge im Schädelbau der Feuerländer zu bestätigen, zu denen GUSINDE und LEBZELTER vor kurzem in ihren vergleichenden Untersuchungen gekommen sind.

a) Norma verticalis. b) N. basilaris. c) N. lateralis. d) N. frontalis. e) N. occipitalis.
$^1/_3$ *natürl. Grösse.*

(Phot F. Jonasson)

ACTA GEOGRAPHICA 4. No. 2

GEOLOGICAL INVESTIGATIONS IN THE CORDILLERA OF TIERRA DEL FUEGO

BY

E. H. KRANCK

WITH 14 ROCK-ANALYSES BY L. LOKKA.
1 MAP, AND 133 FIGURES IN THE TEXT
AND ON 32 PLATES

HELSINKI — HELSINGFORS 1932

PRINTED BY
SUOMALAISEN KIRJALLISUUDEN SEURAN KIRJAPAINON OY.
HELSINKI 1932

To the memory of Professor

Wilhelm Ramsay

this work is dedicated by the author

TABLE OF CONTENTS

PREFACE.

The observations quoted in the following paper were made during an Expedition to Tierra del Fuego and South Patagonia in 1928—29 at the instance of The Geographical Society of Finland. The leader of the expedition was Professor V. Auer. Mr. H. Roivainen took part as botanist and Dr. E. Hyyppä acted as Prof. Auer's assistant.

The main object of the undertaking was to investigate the development of the peat-bogs of the southernmost parts of South America, which work was carried out by Professor Auer and his assistants. Professor Auer was kind enough to give the present writer an opportunity of joining the expedition, and of making geological researches in these interesting and little known regions.

The western part of the Fuegian Cordillera was visited together with Professor Auer. Mainly owing to the courtesy of Mr. Groth-Hansen of Magallanes, who most generously aided my work, I had an opportunity of visiting the southern archipelago of Tierra del Fuego during Professor Auer's stay in the swampy central parts of the Main Island.

The expedition was financed by grants made for the purpose to the Geographical Society and the Geological Society of Finland by the Finnish Ministry of Education, and partly also by private donations from OY Kansallis-Osakepankki and Suomalainen Tiedeakatemia (Finnish Academy of Science). These various donations were received owing to the interest shown by the Ministers of Education, Mr. J. Ailio and A. Kukkonen, Senator A. O. Kairamo and Director A. K. Cajander. Further I desire to express my gratitude to Professor J. J. Sederholm and the late Professor J. E. Rosberg, and also to Dr. H. Renqvist, who have all taken an active part in the preliminaries of the expedition.

Our expedition has much for which to thank the Chilean and Argentine officials, who granted us numerous advantages during our stay in the Magallanes Territories. A special note of thanks is due to Dr. José Sobral, the then director of Dirección General de Minas in Buenos Aires.

The preparing of the collections has been made possible through pecuniary assistance granted by the Geographical Society of Finland. I herewith beg to express my thanks to the Society and to all those who have aided my work.

Further, I desire to express my thanks to my fellow-workers, above all Professor Auer, and also Mr. Samsing, of Magallanes, for good fellowship during the expedition.

Finally, I also wish to thank my collaborator, Dr. L. Lokka, who has undertaken the important chemical investigations of the rocks, and thereby filled a deficiency in our knowledge of the Andean rocks.

In especial the interpretation of the tectonical geology of the Fuegian Cordillera was greatly facilitated by the writer being afforded an opportunity of studying in the field the tectonics of the Swiss Alps during the summer of 1929. I here also desire to express my gratitude to Dr. E. C. Wegmann for his inspiring guidance and valuable advice during these excursions.

I am also indebted to Professor P. Quensel in Stockholm for permission to use the collections of the Swedish expedition to Tierra del Fuego 1908 and to Professor H. G. Backlund for the time I spent in study at the Mineralogical Institution of the University of Upsala.

The laboratory work has been carried out at the Mineralogical and Geological Institution of the University of Helsingfors (Helsinki). I am very much obliged to the Director of the Institute, Professor P. Eskola, for his kindness and interest during these researches.

E. H. Kranck.

Helsingfors, February 1932.

I. INTRODUCTION.

The time spent in the field during the Finnish Expedition to the Magallanes territories being only about five months, there were no opportunities to make extensive systematical detail-observations. The work was mainly directed towards: 1) the investigation of a number of special-problems, particularly the main-features of the structural geology of the Cordillera and 2) the collection of a serviceable material of rock-specimens and exact local field observations from the regions visited. About 500 specimens were collected during the journey, mainly from the central parts of the mountain-range.

The most important result of the investigation is of course the description of the field-observations and the collections, which forms the main part of this paper. The author has in the following tried to keep the observations as far as possible away from theoretical interpretations, and to define the geographical localities with sufficient exactitude to allow of their being used by future investigators. The localities treated in the text are found on the cursory-map p. 223.

In spite of the incomplete material the author has dared to draw some general conclusions, because several questions not taken into account in earlier descriptions of the geology of Tierra del Fuego have of late become objects of increasing interest.

In the interpretation of the tectonical conditions in the Cordillera, the theories used for the Alps generally have been taken into consideration. Especially the Central-European theories about the origin of the crystalline schist-structures in connection with the orogenic deformation of rocks proved very serviceable, as a valuable complement to the field-observations, in the investigation of the tectonical style of the mountain-chain. The conceptions set forth in the following are in accordance with the fundamental works of Sander, Schmidt, Becker and others.

The petrological descriptions have in the following been restricted to a short summary, mainly comprising data of interest in the clearing up of the stratigraphical and tectonical conditions of the Cordillera. Detail-descrip-

tions have in general not been given, in order not to make the work too extensive. Only the Andean diorites are treated more in detail.

The descriptions of the rock-structures are in many cases completed by microphotographs, and also in other cases the author has tried to give the illustrations as an addition to and not as a repetition of the text.

The theoretical conclusions drawn are to be taken merely as a contribution to the discussion about the geology of the southernmost Cordillera of South America, not as any definite result. They have been published mainly to attract interest to a number of problems which seem to be of importance, not only for the solution of the geological conditions of Tierra del Fuego, but also of those parts of the Cordillera which are situated north of the Strait of Magallanes.

The difficulty of obtaining in North Europe literature on South America has in many respects made the list of references incomplete, and the author is aware of the deficiency of the work in that respect. Regarding the names in the paper, it may be pointed out that as a rule the official, Spanish forms have been used.

The altitudes determined are taken with the altitude-meter System Paulin (Stockholm). The panoramic pictures have been taken with panorama Kodak 26.3 × 8.4 cm. (Rotating Zeiss, Tessar objective 1 : 6.8). On the original picture 10 degrees of the horizon correspond to 2.2 cm.

II. MAIN FEATURES OF THE PHYSIOGRAPHY OF THE CORDILLERA OF TIERRA DEL FUEGO.

The South American Cordillera — *La Cordillera de los Andes* — extends as an unbroken mountain-range along the Pacific coast of the continent as far south as the tracts north of the Strait of Magallanes. Here the almost straight north-southerly trend changes into a northwest-southeasterly one, the mountains becoming in some degree lower, and for the first time since the Central-American arches, the sea penetrates in several places through the Cordillera.

South of the Strait of Magallanes the mountains rise to a considerable height, reaching about 3000 m above the sea. The direction of the main ridge[1] bends again and is on the south part of Tierra del Fuego almost parallel with the south coast, *i. e.* about west-easterly.

With their snowcovered peaks, their extensive ice-fields and immense glaciers, reaching right down to the coast through the impenetrable, dark green subantarctic »rain-bush» the mountains of the Fireland form perhaps the most wonderful part of the Cordillera of South America.

The sector of the Cordillera belonging to Tierra del Fuego is only to a small extent situated on the Main Island. The southernmost and westernmost ridges are traversed in several directions by innumerable straits and fjords, and form a very complicated archipelago which comprises more than $^2/_3$ of the territory generally referred to as Tierra del Fuego. South of the Main Island the most important of the islands of this archipelago are Isla Navarino, Isla Hoste, Isla Gordon and Isla Stewart, Isla Dawson, Isla Clarence, Isla Santa Ines and Isla Desolaçion lying to the west.

These tracts are of a very wild and inhospitable nature. In the Pacific region the heavy precipitation has given rise to a very luxuriant and dense though low forest vegetation, up to the forest-limit at about 600 m above sea-level. Only the outermost islands and slopes open to the almost continuous

---

[1] Cordillera Carlos de Rumania, *c/r* HYADES 32.

strong winds are bare and covered with moss-like vegetation. From 800 to 1000 m all the mountains are covered with snow and ice. Farther eastward the climate gradually becomes dryer and the forests, consisting mainly of *Nothofagus pumilio,* grow higher.

The Cordillera-region is not settled, except for a small population around the eastern part of Canal Beagle and in the eastern part of the Cordillera around the Strait of Magallanes on the north-coast of the Main Island and on Isla Dawson.

The highest, central part of the mountain chain runs along the south coast of Peninsula Brunswick, over Isla Clarence to the Main-Island of Tierra del Fuego, where it follows the south coast as far as to the Strait of le Maire. Before it definitely dives underneath the Atlantic ocean it emerges for the last time on Islas Estados (Staten Island).

The Cordillera of Tierra del Fuego may be divided into the following natural groups:

A. The Central-Cordillera,

B. The Coast-Cordillera,

C. The Marginal-Cordillera.[1]

(The last subdivision comprises the archipelago south and west of the Main Island).

This division is in general the same used earlier by several authors *i. a.* NORDENSKJÖLD, QUENSEL, BONARELLI, etc. (40, 41. 45, 11).

A. The Central-Cordillera comprises on the north side of the Strait of Magallanes the southern part of Peninsula Brunswick, and of the islands of the archipelago the northernmost part of Isla Santa Ines and the whole of Isla Clarence. On the Main Island it embraces the area bounded by Canal Cockburn, Canal Magdalena and Canal Gabriel, Paso Cascado, Seno Almirantazgo (Almiralty sound), Lago Fagnano and the south coast of the Main Island of Tierra del Fuego. Only the western part of Peninsula Brecknock is not to be reckoned to this part of the mountain chain.

The topography of I s l a S a n t a I n e s is still almost unknown. On the northern part of the great island the mountains rise to a height of about 1000 m above the sea. Seen from the shore the forms of the crests are almost Alpine. Several deep fjords, generally in the direction N-S, cut several km into the

[1] In the following the term Marginal-Cordillera has been used instead of Pre-Cordillera, in order to avoid a stratigraphic parallelization with the Pre-Cordillera of the Andes of Northern Argentina etc.

highland. The interior seems to a great extent to be covered with ice-fields, and numerous glaciers descend to the coast (Fig. 57 p. 141). Also Isla Desolación is mountainous, though lower than Isla Santa Ines.

Isla Clarence is of a nature similar to the foregoing, particularly along the north coast; in the south-eastern part it is generally somewhat lower, the elevation being less than 1000 m. The island is intersected by several cross-valleys in the same north-southerly direction as the fjords of Isla Santa Ines. In at least three places they cross the whole mountain-ridge from the north coast to the south. The deepest of these valleys forms a narrow channel, hitherto unsurveyed, called Canal Acvalisuan, which divides the whole island into two separate parts; the easternmost has been called Isla Capitan Aracena. Another big valley extends from Seno Mercurio (Mercury Sound) on the south coast to Seno Staples (Staples Sound) on the north. The main part of this valley is occupied by a lake about 6 km long and a couple of km broad. Only a narrow isthmus of 1 $^1/_2$ km breadth separates this lake from the two fjordlets named above. The Finnish expedition named the lake Lago Laina (*cfr.* p. 41). From Seno Mercurio a more westerly arm runs several km northward, forming another cross-valley, which extends through the greater part of the island.

A cross-valley of the same kind and with the same direction forms the Canal Barbara, the strait between Isla Clarence and Isla Santa Ines (Fig. 5). The north-southerly direction of the cross-valleys seems consequently to be one of the most conspicuous features of this part of the Cordillera.

The westernmost part of the Cordillera of the Main Island, *Isla Grande de la Tierra del Fuego*, is a waste mountain-region, crossed by a system of long fjords which divide it into the following well separated areas:

1. The high peninsula between Canal Gabriel, Seno Keates and Fjordo De Agostini, which in the following may be called Peninsula Buckland after its highest mountain.

The north end of the peninsula is comparatively low with rounded ice-sculptured cliffs. The contrast is very sharp between the flat profile of Punta Anxious, the north-point of Peninsula Buckland, and the opposite coast of Canal Magdalena, where the mountains of Isla Clarence rapidly rise to 5—600 m above sea-level. Farther south-west the mountains gradually become higher and already on the south shore of Canal Gabriel they reach a height of about 700 m. The comparatively flat crest is here covered by extensive glacierfields, from which one big glacier flows in a northerly direction down to the valley of Puerto Tristeza.

Between Paso Cascado and Seno Keates the peninsula is very low and narrow — only a few km in breadth; several broad valleys stretch from one coast to the other. The highest part is situated south of this isthmus. North of Fjordo De Agostini it is covered by wild, bold mountains — the Monte Buckland group — visible far out to the Whiteside Channel. The mightiest of these imposing mountain-giants are Monte Buckland (Fig. 15, p. XIII), Monte Sella (Fig. 16, p. XIII), Monte Biella (Fig. 20, p. 67) and Monte Aosta (*cfr.* De Agostini 1, p. 110).

Fig. 1. Monte Sarmiento seen from Bahia Plüschow.
Photo. V. Auer.

2. The isolated mountain-group bounded by Fjordo Martinez, Seno Keates, Canal Cockburn and Fjordo Negri. It will in the following be called Cordillera Sarmiento after Monte Sarmiento, the most famous peak of the western Cordillera (Fig. 1). Cordillera Sarmiento is separated from the eastern part of the High-Cordillera of Tierra del Fuego by a low valley, which crosses the mountain range from the south end of Fjordo Martinez to the south coast of the island. The highest, dominating mountain of the group, Monte Sarmiento, attains 2500 m above sea-level, the other mountains as a rule do not exceed 1000 m in height.

Thanks to the investigations of pater De Agostini (1) Cordillera Sarmiento belongs to the topographically best known part of the regions now under discussion. In his description of his journeys on Tierra del Fuego (»Miei Viaggi nelle Terra de Fuoco») he has published a sketch map of the regions around the Martinez and De Agostini fjords, which gives an idea of the situation of some of the principal valleys and summits of the region. On this map the central-mountain Monte Sarmiento evidently is located some km too far northward.

3. Finally there is the highland between Fjordo De Agostini and Fjordo Martinez; an independent mountain group which only in the south hangs together with the rest of the Cordillera. The Finnish expedition named this highland Cordillera Presidente Ibanez after the then President of the Chilean Republic. It forms a single *massif* with a comparatively even, high plateau, from which solitary peaks reach up to 1500—1600 m. The average height is about 1300—1400 m. The slopes to the sea coast are fairly steep, and only some short glacier-valleys cut through the mountain-walls of the fjord-coasts. The crests are completely ice-covered (Fig. 2).

Farther eastward from the tracts south of the two big fjords mentioned above, extending to the east part of Canal Beagle, follows the highest and also least known part of the Central-Cordillera, Cordillera Darwin. It is an extremely wild and inaccessible alp-land with sharp ice-covered peaks and deep valleys, which are completely filled up with glaciers and small glacier-lakes. The highest ridge of Cordillera Darwin (about 3000 m above sea level) is situated about south of Bahia Ainsworth and Fjordo Parry, and in clear weather its broad icy summits may be seen from the town of Magallanes. The glaciers of Cordillera Darwin are the most famous on Tierra del Fuego.

The broad glacier valley which crosses the mountain range west of the summits Monte Bowen and Monte Frances and which, according to De Agostini (1, p. 191), extends from Fjordo Parry to Canal Beagle, may be regarded as the eastern boundary of this group.

From the central-part of the Cordillera three important valleys stretch to the north coast down to Seno Almirantazgo. From east to west these are: the valleys 1) of Fjordo Parry, 2) of Bahia Ainsworth and 3) of Bahia Brookes (*cfr.* p. 68).

East of Cordillera Darwin follows the Monte Bowen group with the two high peaks Monte Bowen and Monte Frances (1400 and 1500 m) (Fig. 3). Towards the east the Monte Bowen group is bounded by the deep

Jendegaia valley, which also separates the High-Cordillera from the lower parts of the mountain range farther east.

In the latter direction the Cordillera gradually becomes lower, while only its highest ridges are covered with ice and perpetual snow. Already here the valleys are filled with dense, high forests, and therefore the different mountain *massifs* are more sharply defined than in the western Cordillera, being also easier to reach from the coast. The main groups of the eastern Cordillera north of the east part of Canal Beagle are the following:

1. Los Pyramides. The narrow mountain ridge separating Bahia Jendegaia from the broad Lapataia-valley. It descends abruptly to NE, more gently to SW. In the northwesterly direction it seems to be coherent with the mountains of the Darwin Cordillera.

2. Sierra Valdivieso. This name is used on the Chilean and Argentine maps to denote the broad mountain chain which constitutes the water-shed between Seno Almirantazgo, Lago Fagnano and Canal Beagle. It consists of several mountain groups separated from each other by deep valleys. The highest part is the Cerro Svea *massif* (about 1500 m) which rises south of the upper Betbeder-valley.

3. Montes Martial. The beautiful mountain ridge which rises beyond Ushuaia with a comparatively even crest in which glaciers have cut out some small »Kar»-valleys (Fig. 4). It is separated from Sierra Valdivieso by the Rio Grande valley, in its upper part a narrow gorge with steep slopes. Between the two last-named mountain-complexes there is further an isolated highland, consisting of the mountains lying east of Lago Roca (Agicami) and the lower part of the Rio Rojas (Lapataia) valley (*cfr.* p. 90).

4. The Monte Olivia group east of Montes Martial, separated from this ridge and Sierra Valdivieso by the Rio Olivia valley. The highest summits are Monte Olivia and Monte Cinco Hermanos (Fig. 53, p. XXIII).

5. Cordillera Alvear, the long ridge forming the watershed to Lago Fagnano in the eastern part of the Cordillera. It is separated from the Monte Olivia group etc. by the broad, long Carabajal valley, which divides the Cordillera into two parallel ridges (Fig. 52 p. XXIII). South of the valley we have east of Monte Olivia another comparatively high group, which on the maps has been called Sierra Sorondo (Fig. 4 p. II).

The summits of Cordillera Alvear attain in its western parts over 1400 m; in the easterly direction they gradually become lower.

The mountains of Sierra Sorondo do not as a rule reach an elevation of more than about 1000 m and glaciers are wanting. In contrast the Alvear

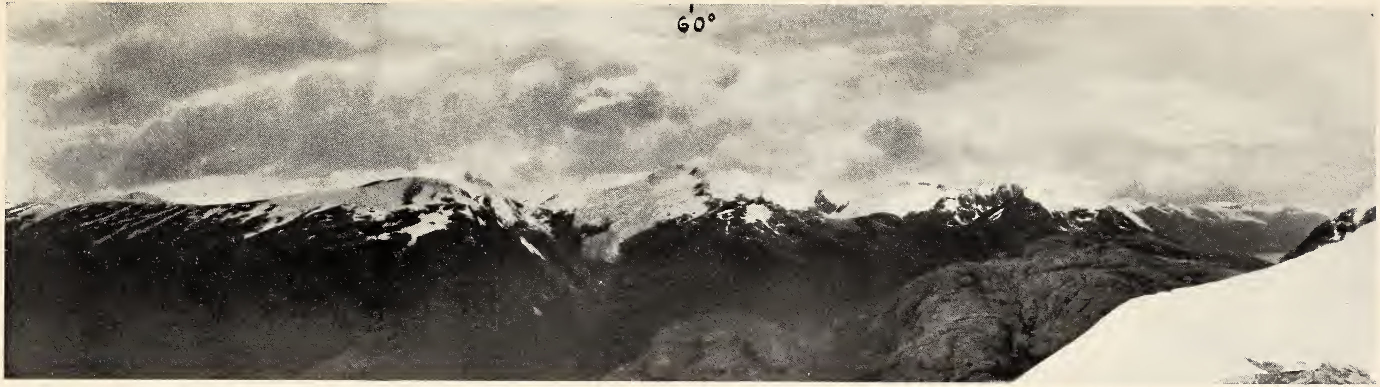


Fig. 2. The southern slope of Cordillera Presidente Ibanez in the Central-Cordillera of Tierra del Fuego. The highest mountains are covered by clouds. Looking from the mountains E of Bahia Plüschow.
Photo. E. H. K.

Fig. 3. Landscape from the »Channels» of Tierra del Fuego. Canal Beagle looking eastward from the SW-arm near the junction with the SE-arm. On the left side the Monte Bowen group, on the right the mountains of Isla Hoste are visible.
Photo. E. H. K.

Fig. 4. The north coast of Canal Beagle, east of Ushuaia. On the right side the mountains of Sierra Sorondo, on the left the even crest of Montes Martial.
Photo. E. H. K.

Fig. 5. Landscape from the Coast-Cordillera. The S inlet of Canal Barbara surrounded by ice-sculptured mountains consisting of Andean diorite.
Photo. E. H. K.

Cordillera and Olivia group show some small glaciers, and also on Montes Martial there is a small remnant left, on the south-west side.

When we leave the Beagle Channel the mountains on the south coast of the Main Island of Tierra del Fuego become lower and the crests have a plateau-like shape with a height of only about 600 m above sea-level. In the easternmost part of the island, on Peninsula Mitre or Polycarpo, they again become higher, and on Islas Estados (Staten-Islands) they rise to more than 1000 m.

B. The Coast-Cordillera of Tierra del Fuego. This name is here used to designate the outer part of the Cordillera-arch, mainly occupying the big islands along the Pacific coast. It is consequently not applied as an orographic term in the sense intended by SUESS, STEFFEN (54) and QUENSEL (45), who have all combined the appellation with morphological or geological data (*cfr.* also BONARELLI, 11). QUENSEL comprehends with this term the fjord area of southern Chile and mainly the Andean diorite region. SUESS' interpretation is coincident with that of QUENSEL, but he groups it together with the hypothetical longitudinal valley of the East-Andes.

In the following the name in question is used only as a regional designation, without any morphological meaning.

The big islands of Tierra del Fuego are without exception mountainous and to a great extent glaciated. The coasts of the islands generally descend rapidly from the shore line to 6—700 m. The inner parts are almost unknown and difficult of access, partly in consequence of their height and glaciation, partly owing to the extremely dense forest vegetation — the rain-bush — on the lower parts of the slopes; both causes being mainly a consequence of the high rate of precipitation.

These mountain formations are rarely as wild and bold as those of the High-Cordillera, and only in exceptional instances do the summits rise higher than 1200 m.

Also the greatest part of Peninsula Brecknock belongs geographically to the same region as the archipelago south of the Main Island. The peninsula is completely filled up with mountains with rounded crests, rising to a height of about 600 m, and peaks rising to 8—900 m. The landscape is highly glacier-sculptured, but recent glaciers are lacking. The vegetation is very poor, the forest-growth consisting only of creeping brushwood on sheltered places.

The big islands Isla Stewart, Isla Londonderry and Isla Gordon also show a similar natural aspect. Of these only the latter island

Fig. 6. Puerto Valdez on the west coast of Isla Dawson. The mountains consist of Cretaceous sandstone and conglomerate and show the typical topography of the Marginal-Cordillera. Photo E. H. K.

has been visited at various points by scientific expeditions, while even the coastline of the two others is but imperfectly known.

The big Isla Hoste, with an area of more than 10000 km², is also a highland with but few and small coast-valleys. The map shows that it is greatly broken up by numerous long fjords which divide it into several mountain-groups. The direction of these fjords is less regular and dependent on the structure of the Cordillera than in the central parts of the ridge.

The highest mountains are situated in the westernmost part, on Peninsula Cloé, the inner high-plateau of which is covered by large ice-fields. The middle of the island is a little lower; the mountains are in general not higher than 5—600 m, and numerous valleys traverse the ridges from one coast to another. The south-eastern part is again higher and traversed in the general direction WNW-ESE by the high, ice-covered Alpes Fueginas, whose snowy summits rise to 900—1000 m.

On Peninsula Hardy, the southernmost part of Isla Hoste, which extends down to the vicinity of Cape Horn, the mountains already are lower and more easily approachable, without forming continuous ridges of considerable height.

The north-eastern part of the island forms the Peninsula Dumas. Here the mountains reach their greatest height on the north-eastern side, where Montes Sampaios (Fig. 49, p. 122) rise to 1300 m above sea-level. Farther east the mountains are lower again and the crests more flat.

The character of the easternmost of the big islands south of Tierra del Fuego, I s l a N a v a r i n o, differs in many respects from that of the other islands. The topography is only in a slight degree of cordillera character, the main part of the island being a wood-covered hill-land, where the ridges rarely are more than some hundred metres high (Fig. 54, p. XXIV). Only along the north coast have the mountains in part a more Alpine character, with sharp peaks reaching above the forest-line. Here also the highest mountain of Isla Navarino, Pice Navarino, is situated (1190 m above the sea). On the greater part of the island the mountain-crests are almost plateau-like, resembling those of the Cordillera of the Main Island north of East-Beagle and on Peninsula Mitre. The plateau-height is as a rule about 600 m (*cfr.* p. 130) Owing to the absence of deep, drowned valleys the coastlines are remarkably straight. The southern coast of Isla Navarino is low.

The islands Lenox, Nuevo, and Picton show the same character as Isla Navarino, while the other smaller islands of the southern archipelago belong to the same morphological type as the cordillera fragments described earlier.

T h e W o l l a s t o n i s l a n d s are also comparatively low and seem to belong to the outmost ridges of the Cordillera.

C. The Marginal-Cordillera comprises the large highland north and northwest of the Central-Cordillera, which consists of several lower parallel-ridges, generally following the main direction of the latter, though they have a different morphological aspect.

They occupy the land between Seno Almirantazgo — Lago Fagnano and the pampa-area on the north side of the Main Island of Tierra del Fuego. The mountains of Isla Dawson and farther north the middle part of Peninsula Dumas are also of a corresponding nature.

On Isla Grande the northern boundary of the Marginal-Cordillera may be reckoned from the region south of Bahia Inutil (Useless bay) south of Rio Grande, in a south-easterly to easterly direction to the east end of Lago Fagnano. This mountain stretch, which has its greatest breadth north of Seno Almirantazgo, gradually narrows towards the east and at the east end of L. Fagnano it consists only of some rather low ridges separating the lake from the pampa. The Marginal-Cordillera on the easternmost parts of Tierra del Fuego is but very imperfectly known. East of Lago Fagnano a ridge called Sierra Irigoyen rises over the surrounding hills, which judging from existing descriptions are generally comparatively low.

The mountains of the Marginal-Cordillera attain a considerable height, especially in the extensive highland north of Seno Almirantazgo, with crests of

more than 800 m above sea-level. The form of the mountains is, however, always very even and is nowhere Alpine in character. Sharp summits are lacking (Fig. 6). Perpetual snow is nowhere present, but on the higher crests patches of snow are found in sheltered places at all seasons of the year. The valleys are covered with high, dense woods, or big swamps. The climate being here considerably dryer than in the High-Cordillera, the vegetation is variable and rich and the mountains have no glaciation (Fig. 6, p. 18 and Fig. 7, p. III).

III. REVIEW OF EARLIER GEOLOGICAL RECONNAISSANCES OF TIERRA DEL FUEGO.

Compared with many other parts of the South American Andes, the Cordillera of Tierra del Fuego is fairly well known from a geological point of view; far better than for instance the sector north of the Strait of Magallanes.

Tierra del Fuego has several times been the subject of scientific and ethnographical investigations. Different parts of the country have been visited by expeditions both from South America and other parts of the world, more particularly towards the end of the last century and at the beginning of the present one. On the other hand, no more comprehensive undertakings have been carried out during the last two decades.

The rough nature of the distant regions has rendered research-work very difficult, and the investigators therefore still find many new and interesting problems awaiting a solution. The lack of serviceable maps partly accounts for the incomplete knowledge of the country.

Owing to the circumstances named above, a systematic geological survey of Tierra del Fuego has not been carried out. In spite of this, the observations and collections of the different expeditions give a fairly good picture of the general lithological composition of the southernmost end of the Cordillera of South America, and of the petrological character of the rocks occurring there.

The most conspicuous feature of the geology of the south end of South America, both of the main-land and of Tierra del Fuego, is the asymmetric structure with flat-lying, unaltered sediments on the east and north-east side and the more or less crystalline, strongly folded rocks of the Cordillera to the west and south-west. These two main features were fixed already by Ch. Darwin (1837), the first explorer who has given exact geological data of importance from the Magallanes territory (17).

Within the Cordillera, he pointed out the difference between the highly crystalline rocks of the central-parts of the range (Cordillera Darwin), and the comparatively well preserved, slaty rocks of the Marginal-Cordillera and the tracts around the eastern part of Canal Beagle, belonging to the so-called

»clay-slate-formation» of DARWIN. The name is still often used and will be found in a slightly modified sense also in this paper. Fossils found in the schists of Monte Tarn on Peninsula Brunswick led DARWIN to determine the age of this formation as Cretaceous. According to later investigations the slate-formation of Canal Beagle is after all probably older, and in the following the appellation will be restricted to the younger series. Also the igneous rocks, and more particularly the dominating rôle of these rocks in the Pacific zone, was pointed out by DARWIN.

The investigations of DARWIN are not restricted only to his petrological and paleontological observations, which still hold true in almost every point, but he has also with admirable penetration interpreted the tectonical structure of the mountain-range, perhaps more correctly than any later writers.

The scanty data which we possess about the geology of Tierra del Fuego from earlier days are of less interest. Concerning these we refer to bibliographic notes by DARWIN and HYADES (see below).

It was not till the end of the 19th century that knowledge of the geology of Tierra del Fuego took a step forward, this being then due to the observations of the geologist of the French Cape Horn-expedition (Mission Scientifique de Cap Horn, 1882—83), Dr. HYADES (32), and of Prof. LOVISATO, who visited the country the year before with the BOVE expedition (1881).

The French expedition, often also called the Romanche expedition, worked mainly in the archipelago south of the Main Island, using the mission-station at Orange-bay on the south part of Isla Hoste as a base. The greater part of the rock-specimens described derive from the west and south coast of the latter island, but also rocks from other parts of the southern archipelago are treated in great detail. Though the data about the geological relation of the rock-types described are rather imperfect, the work of HYADES still gives the best available description about the geology of the region.

The observations of HYADES are completed by the observations and rock-collections of LOVISATO, referring mainly to Canal Beagle and Islas Estados (32).

Of great stratigraphic importance was the discovery of fossil remains in the schists of the eastern part of the Cordillera, reported by the French expedition. These discoveries made it probable that the formations were of later origin than the metamorphic schists of the Central-Cordillera. HYADES pointed out the similarity between the last-named schist and the strongly tectonized rocks of the central parts of the European Alps, and assumed a similar origin of both the rock-types. Later descriptions have generally laid far less stress

on this circumstance, the alteration commonly being connected with contact metamorphose caused by intruding granites (QUENSEL, 45, BONARELLI, 11). It may be pointed out that the interpretation of HYADES was put forward at a time when the central schists of the Alps to a greater extent than is now the case were believed to be of high age, probably pre-Cambrian.

In the summer 1895—96 the same regions were visited by Dr. OTTO NORDENSKJÖLD, the leader of the Swedish Expedition to the Magellan Territories 1895—97 (40, 41, 42). The most important result of his investigations was the detailed description of the so called Andean diorites [1], the big granitic and dioritic rock-complexes of the outer Pacific sector. He pointed out the petrological relation between these rocks and similar rock-types in other parts of the American Cordillera right up to Alaska. The age of the Andean diorites was believed to be Tertiary, mainly on account of their unaltered condition. NORDENSKJÖLD collocated the result of the field investigation to the first geological Map of the Magellan-Territories (40).

Three years earlier the Swedish Antarctic Expedition, also under the leadership of NORDENSKJÖLD, made some landings on the South part of Tierra del Fuego. During one of these landings GUNNAR ANDERSON (2) made the first investigation of the important fossil-locality of Tekenika bay on South Hoste, discovered by DANA. Unfortunately the collections were lost, when the expedition's ship was wrecked (1891).

Not still seven years later were fresh researches made at this place, also this time by a Swedish expedition, *viz.* »The Swedish Expedition to Patagonia and Tierra del Fuego» under the leadership of C. SKOTTSBERG. The paleontologist on the journey, T. HALLE, visited Tekenika and was able to prove that the plant fossils collected there derive from older or middle Jura (30). Unfortunately, the animal-fossils representing a number of mollusc-specimens are yet undetermined. They might possibly give a more exact age-determination of the sediments of this locality.

The geologist of the Skottsberg-expedition, P. QUENSEL, mainly investigated the younger volcanics of the Cordillera (45, 46, 47) particularly in South Patagonia, but also in Tierra del Fuego. He proved that the Andean diorites form almost the whole of the outer part of the archipelago from Cape Horn to Puerto Montt. QUENSEL also gives a petrographic description of a group of granites which NORDENSKJÖLD reported from boulders on the south coast of Tierra del Fuego, and which differ from the common Andean diorites in

---

[1] In the following the appelation Andean diorite will be used as a synonym for Andendiorite.

respect of their more tectonized character. He found granites probably belonging to this group occurring in Cerro Svea, south of Lago Fagnano. A special description was devoted also to the interesting old quartz-porphyries of Valle Azopardo.

No geological investigations of importance have been made in the Cordillera since the Swedish expeditions worked on Tierra del Fuego. Later investigations concerning the Magallanes territories deal mainly with the fossil-bearing formations outside the mountains, and have chiefly a paleontological significance. They have, however, in a very high degree increased our knowledge of the stratigraphy of the Marginal-Cordillera and more particularly of the Tertiary beds on its eastern side.

The most important of these researches are the investigations of FELSCH (21, 22) concerning the Tertiary formations around the Strait of Magallanes (1912). Still later, PASTORE and DUELLO HURADO (18) have carried out investigations in the Cretaceous formations on the northern part of the Main Island of Tierra del Fuego. Only some small preliminary notes on the results have hitherto been published.

The newest compilation of the geology of Tierra del Fuego is contained in G. BONARELLI's work on the peatbogs of the Magallanes territories (1912, 11). BONARELLI gives a critical summary of researches published up to that date, and with the aid of this examination draws a new small scale geological map of the country. We shall in the following have cause to revert to the work in question.

As shown in the summary given above, the earlier investigations dealing with the Cordillera of Tierra del Fuego give a comparatively good picture of the petrographical character of at least some parts of these mountains. In contrast to this, the data at hand about the geological relation between the different rock-types is very scarce. This is owing to the fact that field-observations are made mainly along the coast from the ship and at occasional, short landings, and are therefore very superficial. Also the observations described in the present paper suffer to a great extent from the same fault.

Before entering on a description of the localities visited by the present writer a short review of the main elements of the geology of Tierra del Fuego may be given. Schematically these can be subdivided in the following way:

1. The Magellanean beds of the pampa.
2. The Cretaceous »Flüsch»-sediments of the Marginal-Cordillera.

3. The metamorphic schists of the Central-Cordillera.

a. The high-metamorphic, micaceous and quartzitic schists of the Darwin Cordillera and its westerly and easterly continuation.

b. The argillitic and phtanitic schists of the Beagle-regions and the north front of the Central-Cordillera (the Monte Buckland and the Yahgan-formation *cfr.* p. 61 and 101).

4. The Andean diorite (Anden diorite) of the Coast-Cordillera, and its related effusives.

1. The open plain-land of Tierra del Fuego is underlain by Tertiary molassic layers in almost undisturbed position. They resemble the »Pampa formation» of Patagonia and are generally of the same age, probably in part a little older (*cfr.* 31, 33 and 11). They consist of yellowish sandstones and gravel-conglomerates interstratified with marl-layers rich in fossils, mostly of marine origin. These, the so-called Magellanean beds, have, so far as we know, not been influenced by the orogenic movements of the Cordillera. Only along the foot of the latter are they in some degree lifted up and elevated, sloping gently towards E and N.

In several places, generally north of the Strait of Magellanes, the molasse-formation is penetrated and partly covered by young Tertiary plateau-basalts and their tuffs. NORDENSKJÖLD found rocks of this type at Rio Grande on the north coast of the Main Island (42).

2. Under the Tertiary molasse follow, in the direction towards the Cordillera, Cretaceous sediments occupying the principal part of the Marginal-Cordillera. These consist of dark-coloured sandstones and clay sediments and, especially in the vicinity of the High-Cordillera, of thick beds of conglomerates containing pebbles of the rock-types found in the central mountain ridge.

The boundary between the Tertiary beds and the upper Cretaceous layers is not quite established. A disconformity certainly exists, as WINDHAUSEN has proved, in the region of Lago Argentina in south Patagonia (64) but it is still a matter of discussion, if this is angular, or merely an erosion-interval. The former seems however to be more probable, to judge from *e. g.* the occurrence of lignite layers in undisturbed position at Bahia Slogget on the south coast of the Main Island, in a region where the Cretaceous sediments are strongly folded (*cfr.* 2).

The Cretaceous layers of the Marginal-Cordillera generally have the character of a »Flüsch» deposited along the edge of the older parts of the

mountain-ridge (*cfr.* p. 29) between two phases of orogenic action. They are strongly folded and the layers are tilted in steep, often vertical, positions. This is particularly the case near the Central-Cordillera. The sediments are sometimes brecciated, but never recrystallized in a noteworthy degree. The fossils, which have been found at several places, are mostly of marine origin, but in certain horizons also plant-fossils are present.

3 a. The central core of the High-Cordillera — from the regions north of Ushuaia in the east to Isla Clarence and Peninsula Brunswick in the west and north-west — consists for the most part of strongly tectonized and recrystallized schists, generally of micaceous and quartzitic composition. Together with these is found an abundance of altered greenstones, probably of ophiolitic origin, metamorphosed into chlorite- and talc-schists, etc. The tectonical style of the formation is characterized by overthrust folds or »nappes».

These central schists are penetrated by younger, but still strongly tectonized granites, composing the kernel-parts of the Darwin Cordillera.

b. South, and in part also north, of the schist-formation named above, there are to be found extensive areas of dark slates rich in carbon, forming a great part of the archipelago south of Tierra del Fuego. These are to a great extent of pyroclastic origin, and have the petrographical composition of graywackes and cherty slates, but also normal clay sediments and marls abound. Also this formation is strongly folded in vertical folds and deformed, but is less recrystallized than the foregoing, and contains microfossil remains of marine origin.

Mainly on the boundary between these two types of schists old quartz-porphyries have frequently been found.

4. The outer zone of the Pacific Islands consists of the so called Andean diorites, granitic, dioritic to gabbroidic rocks of youngish aspect. They also form some small isolated areas between central-schists (Isla Gordon, Navarino etc.).

In the southernmost part of the archipelago, particularly on the south coast of Isla Hoste and the Islas Wollaston, effusive rocks of andesitic or basaltic composition are found in several localities. These may partly belong to the Andean diorites, but are in part at least probably also younger. They are known from the descriptions of HYADES and QUENSEL etc. under the name of »propylites».

IV. GEOLOGICAL OBSERVATIONS IN THE CORDILLERA OF TIERRA DEL FUEGO AND DESCRIPTION OF ROCK-SPECIMENS COLLECTED.

A. OBSERVATIONS IN THE MARGINAL-CORDILLERA.

General remarks.

The personal observations of the present writer about the layers of the Marginal-Cordillera are comparatively sparse, his travels mainly embracing the central parts of the mountain ridge. Earlier surveys have, however, made us fairly well acquainted with the geology of the foothills and the frontal part of the Cordillera. Particularly the coast of the Strait of Magallanes north-east of Cap Froward — the south-end of Peninsula Brunswick — has been visited in several places by geologists, while also some places on the coasts of Isla Dawson and the east-coast of Canal Whiteside have been geologically mapped by the State-survey of the Republic of Chile (Dirección de Minas), though the maps have never been published, being available only as photographic copies.

The stratigraphy of this region has been worked out by Forbes, d'Orbigny (44), Wilckens (67) and Felsch (21, 22).

As a result of investigations carried out in 1912, mainly along the coasts of the Strait of Magallanes and the Whiteside channel, the lastnamed author divides the Cretaceous layers of these tracts into the following main-horizons, reckoning from the oldest upward:

a. Dark phyllitic schists without fossils. Occurring at Monte Tarn.

b. Gray and brownish sandstones with carbonatic layers. They contain poorly preserved remains of *Inoceramus* and *Neocomites*. Thickness about 320 m. Locality, highest crest of Monte Tarn. According to Felsch, the age is probably *Cenoman*.

c. Marl, poor in silica, with carbonatic concretions containing remains of *Hoplites* and *Gaudryceras* (Upper *Cenon?*).

d. Mixed marl with plant-fossils.

e. Mixed marl interbedded with sandstone and containing plant-fossils.

f. Layers of hard sandstone of a dark greenish colour, rich in carbonate, containing abundance of animal-fossils, pointing to Upper *Cenon*. Thickness about 200 m.

This outline is founded on comparatively few observations, and will probably in the future be modified in several respects. It gives no definite answer to the important question as to the lower limit of the Cretaceous formation (*cfr.* p. 25).

During the summer 1928—29 detailed stratigraphical investigations were carried out in connection with the petroleum-prospectings of the Chilean State in South Patagonia and Tierra del Fuego. The determination of the fossil-collection obtained by this expedition will probably solve some of the problems regarding the age and stratigraphical sequence in the Marginal-Cordillera of the Magallanes-territories.

In the following a description will be given of a couple of places visited by the present author, which seem to have a more general interest.

Isla Nassau (Puerto San Nicolas) (1).[1]

The rock-ground of the small island Nassau, south of Punta San Isidro, consists of a coarse pebble-conglomerate interstratified with coarse-grained sandstone. This conglomerate seems to be of wide extent in the older layers of the Cretaceous formation of Magallanes, especially in the neighbourhood of the Main-Cordillera. The beds often attain considerable thickness. Rocks of a type similar to that of Isla Nassau are found on the opposite shore of the Strait of Magallanes, on Isla Dawson, on the east-coast of Canal Whiteside, in the hills south of Seno Almirantazgo and in other places. They represent a very typical feature of the Marginal-Cordillera and some lines may therefore be devoted to the occurrence.

There probably exist similar conglomerates of different age; the small occurrences which have been found at several points along the coast of Peninsula Brunswick farther north belong probably to some of the younger horizons; the thick beds of San Nicolas and the middle part of Isla Dawson (*cfr.* p. 32) are evidently basal-conglomerates indicating one of the most important disconformities in the southernmost Cordillera of South America.

The occurrence consists of very coarse material containing big, incompletely assorted, well rounded pebbles of up to 20—40 cm in diameter, often forming banks several metres thick. Between them there are layers of small-grained conglomerate and sandstone. The dip is about 45° NW.

The pebbles consist without exception of rocks occurring in the High-Cordillera. Most abundant are greenstones of several kinds, partly andesitic,

[1] The figures refer to the map Fig. 60, p. 223.

partly diabasic in composition. The first-named resemble completely the effusive rocks belonging to the propylitic effusives (HYADES). They are in part coarse-, in part fine-grained or dense porphyric. These effusive rocks occur now-a-days rather sparingly in the neighbouring parts of the Cordillera, but there is reason to believe that they earlier formed thick lavabeds in the tracts outside the Central-Cordillera (*cfr.* BONARELLI, 11).

The »Flüsch»-beds rested on the old sediments and schists of the Cordillera and were destroyed during the Cretaceous erosion-cycle. All the rocks are completely unchanged, and they show no trace of mechanic deformation, except a slight fissuring formed at the folding of the conglomerate.

Also greenstone-pebbles of a more ancient type abound, corresponding to the metamorphic greenstone schists of the Central-Cordillera.

Another important group of the pebbles belongs to the Andean dioritic rocks. They are partly hypabyssic igneous rocks of ophitic structure, partly gabbros and normal Andean diorites. The latter show all the typical features of this rock-group, and there can be no doubt that they really derive from the coast-batholite, at a fair depth.

These boulders prove further that the Cordillera was deeply eroded at the time when the Cretaceous layers were formed. The Andean dioritic intrusion consequently belongs to a phase of the development of the mountain-ridge very much older than the Cretaceous sedimentation. These circumstances have also been pointed out by BONARELLI, though he gives no observations in support of his suggestion (11).

The sediments in the conglomerate boulders consist mainly of the dark dense schists which we know from the eastern parts of Canal Beagle, Seno Almirantazgo, Peninsula Buckland etc., and they can with great certainty be identified with these formations (the Monte Buckland series). As will be seen later (p. 62), they regularly contain remains of microfossils. In the schists of the conglomerate-pebbles there are exactly similar petrifications, which must be considered as belonging to the same stratigraphic horizon (Fig. 3, Pl. IV).

The high-metamorphic schists of the Central-Cordillera occur but sparingly, evidently owing to the less resistant character of its rather soft mica- and chlorite-rich rocks.

Some pebbles of quartz-porphyry were also observed.

The petrographic character of the most typical rocks occurring in the conglomerate-pebbles appears from the following microscopic description:

Sp. 254. *Granodorite* (Andean diorite). Pebble in conglomerate from Isla Nassau

The structure is hypidiomorphic, medium-grained with idiomorphic crystals of plagioclase embedded between more small-grained quartz. The mineralogical composition is: plagioclase, quartz, biotite, chlorite, titanite, magnetite, apatite, and calcite in small quantities.

The q u a r t z is in some degree granulated, and undulose. The p l a g i o c l a s e shows well developed zonar-structure and twinning according to the albite-, pericline- and Carlsbad-laws. The composition of the inner part of the crystals is 40—45 % An, the outer zone is somewhat more Ab-rich. The b i o t i t e is brownish yellow, comparatively light-coloured and partly altered into chlorite. T i t a n i t e is present in abundance as big idiomorphic crystals, of the common habit. E p i d o t e and c a l c i t e represent the late-magmatic constituents, the former as rather big, partly well-individualised grains, the latter as a fine pigment. The epidote in particular is a very typical constituent of the more acid components of the Andean diorite series.

Another type of the Andean diorites is represented by the following rock, which has a more granitic — adamellitic — character.

Sp. 255. *Hornblende-biotite granodiorite.* Pebble in the conglomerate from Isla Nassau.

The structure is about the same as in the foregoing specimen. The plagioclase shows well developed idiomorphic crystals, and also the hornblende and biotite are fairly well individualized, the other main-components are allotriomorphic. The composition is: plagioclase, quartz, KNa-felspar, hornblende, magnetite, apatite and titanite.

The p l a g i o c l a s e has a beautiful zonar-structure with rather sharp boundaries between the different zones. The structure is not in noteworthy degree recurrent. Twinning according to Carlsbad-, pericline- and albite-laws. The composition in the most predominant zones was determined as follows:

outermost zone	28 % An.
medial zone	39 »
kernel	48 »

The K N a-f e l s p a r is always of late crystallization, the boundaries between this and other minerals are generally uneven and rugged. The grains are clear and unaltered, with signs of perthite-lamellation. The h o r n b l e n d e is of the common green type with pleochroism in yellowish shades. The grains are comparatively big. The optical orientation is $\gamma : c = 17°$. The b i o t i t e is dark reddish brown with normal absorption. A p a t i t e and t i t a n i t e both occur in idiomorphic crystals, the latter has $2E = 34°$.

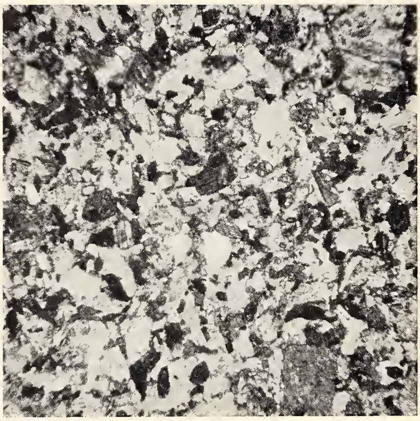
The rock can be regarded as a very typical Andean diorite. Also supercrustal rocks of the same series are represented, of which the following may be cited:

Sp. 258. *Porphyrite.* Pebble in conglomerate from Isla Nassau (Puerto Nicolas).

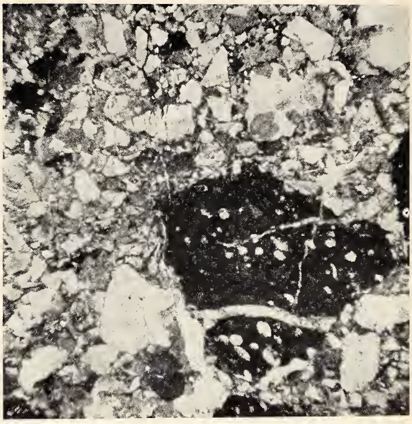
The rock has a porphyric structure with phenocrysts of plagioclase, hornblende and pyroxene in a dense, partly glassy ground-mass. The p l a g i o c l a s e is dull and partly altered and therefore difficult to determine, though it seems to be about 28 % An. The h o r n b l e n d e is very dark green, with but weak pleochroism. The extinction is $\gamma : c = 18°$. The p y r o x e n e-grains are light yellowish, strongly resorbed and partly altered into hornblende and epidote.

Fig. 7. Flüsch-sandstones of the Marginal-Cordillera at Lago Deseado in the central parts of Isla Grande, Tierra del Fuego.
Photo. H. Roivainen.

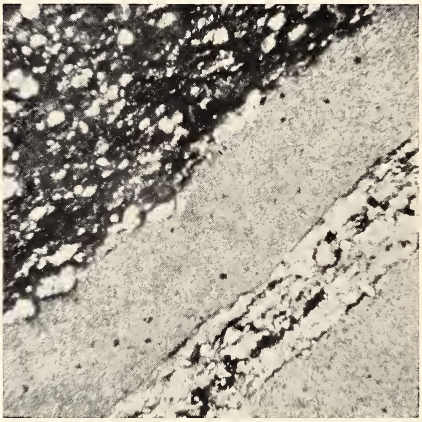
Fig. 8. Folded Cretaceous sediment. Petro Grande near Estancia Vicuna. Central parts of Tierra del Fuego.
Photo. E. Hyyppä.



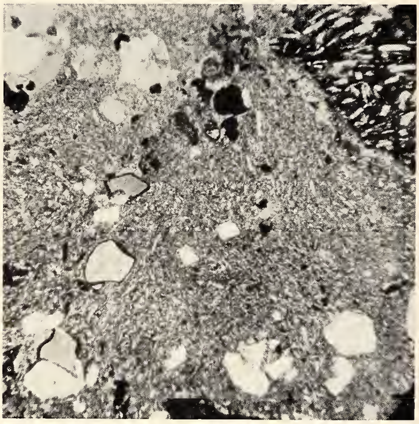
1



2



3



4

5

6

Also porphyries without hornblende were observed. Many of the specimens represent a type which frequently occurs as dike rocks among the Andean diorites (*cfr.* p. 176). The principal dark component is hornblende, of a light green to brownish green type, occurring as dense-packed idiomorphic crystals of varying size (Sp. 251).

Owing to the lack of fossils the age of the conglomerate of Isla Nassau is so far impossible to determine with any great exactitude. Only insignificant remains of shells were observed by the author, though careful examinations would probably give better results in the last named respect. The nearest place where fossils were observed is Punta San Isidro **(2)** some km farther north, where the author found remains of *Inoceramus Steinmanni* and also plant fossils, indicating probable Cenonian age. On the Chilean map Isla Nassau is reckoned to the Neocomian, which appears to the present author fairly probable, taking into consideration the vicinity of the older schists of the Central-Cordillera. On the other hand there might, as later will be seen, exist tectonical complications at this place, which render the age determination without fossils very difficult.

The lighthouse of San Isidro is situated below the classic locality of Monte Tarn.

EXPLANATION OF PLATE IV.

Fig. 1. Cretaceous Flüsch-sandstone. Cabo Espectacion, S end of Isla Dawson. Imperfectly rounded grains of quartz, felspar, pyroxene and hornblende. Magn. 14 ×. Nic. 11.

Fig. 2. Conglomeratic sandstone of the Cretaceous Flüsch-series of Puerto Arthuro. Black inclusions of radiolaria-bearing phtanites belonging to the central-schists (Monte Buckland series). Magn. 19 ×. Nic. 11.

Fig. 3. Phtanite with fragments of radiolarias from pebble of Cretaceous basalconglomerate. Isla Nassau, Puerto Nicolas. S coast of Peninsula Brunswick. Magn. 14×.

Fig. 4. Basaltic lava with intratelluric, resorbed crystals of augite and inclusions of earlier chilled glassy diabase (in the upper, righthand corner). Islas Carlos, Strait of Magallanes. Magn. 15 ×. Nic. 11.

Fig. 5. Melaphyre. Islas Carlos, Strait of Magallanes. Clear plagioclase-crystals with inclusions in central zones. The ground-mass is partly glassy (g), and poor in femic minerals. Magn. 12 ×. Nic. 11.

Fig. 6. The same rock as No. 5 under crossed nicols. C = radially developed calcite. Magn. 12 ×.

Isla Dawson.

The large island Dawson belongs for the most part to the Marginal-Cordillera. Only the northernmost end is already of pampa character. On the southwest coast at Canal Gabriel the sediments show a great similarity with some of the schists in the frontal part of the Central-Cordillera, probably corresponding to the »*serie infracretacico*» of Bonarelli.

Landings were effected on the west coast of the island at Puerto Valdez, and in the northern part of Canal Gabriel, as well as on the east coast, at Puerto Harris.

Puerto Valdez **(3)** is a narrow bay running in a NW-SE-erly direction, surrounded by 3—400 m high mountains, sloping rather gently to the shore (Fig. 5). Outside the bay there are some small islands and the place is sheltered against winds from the outside. The shore of the bay and the valley behind are open, not wooded and some attempts have been made to keep sheep at this place. The valley is, however, very windy and the grass vegetation has not proved suitable for sheepfarming. The small farm-buildings were all empty on the occasion of our visit.

The mountains around the valley consist of folded but unaltered Flüsch-sediments in thick beds. On the north-western slope are found sandstone and a coarse conglomerate of exactly the same type as at Puerto Nicolas. The pebbles in the outcrops near the farm were mainly of volcanic origin. Lavarocks, partly porphyritic, partly dense felsitic, together with dark argillitic schists are the predominating constituents. The thickness of the conglomerate-formation is here at least 200 m. It is partly brecciated but in other respects unaltered.

The sediments dip about 50° towards the NE. The folding-axis seems to have about the same direction as the valley, which is to be interpreted as a longitudinal valley striking more or less parallel with Canal Gabriel.

It is evident that the conglomerate-formation of Puerto Valdez belongs to the same horizon as that of Puerto Nicolas. The great thickness of the beds makes it conceivable that we also here have to do with a basal conglomerate.

A coarse porphyry with big phenocrysts of black augite is particularly abundant among the rocks composing the conglomerate-boulders (Sp. 284).

The ground-mass contains mineral-components of rather varying size, mostly plagioclase in sharp, euhedral crystals and augite. The main-part is vitreous. Carbonate grains, evidently filling up amygdules can often be observed. The plagioclase forms generally short crystals with the composition 50—67 %. The zonar structure consequently is conspicuous. The augite-grains are often more than $^1/_2$ cm in diameter. They are

grayish-green in colour, with almost no pleochroism. The edges of the grains are strongly resorbed. The optical orientation is: $\gamma : c = 46°$, $2V = 42°$.

The andesitic porphyries resemble those described from Isla Nassau.

Sp. 258. *Andesite-porphyry*. Pebble from conglomerate. Puerto Valdez, Isla Dawson.

The structure is porphyric with phenocrysts of plagioclase, hornblende and pyroxene in a very fine-grained ground-mass, consisting of plagioclase, hornblende, magnetite, apatite and chlorite.

The plagioclase phenocrysts have a diameter of about $^1/_2$ cm. The composition of the main-part of the grains is 50 % An. The hornblende occurs as black needles attaining a length of up to $^1/_3$ cm. The absorption is γ (dark brownish-green) $>$ β (green) $>$ α (yellowish-green). $\gamma : c = 14.°5$. Pyroxene is present only in small quantities as small light-green grains with corroded edges. 2E is about 55°.

In addition there are ultrabasic porphyries with big, rounded, dense-packed olivine crystals.

Canal Gabriel. From Canal Gabriel we have some geological data provided by earlier expeditions (FITZ-ROY, DARWIN, BONARELLI) which seem to prove that the sediments on the northern shore are Cretaceous, at least in the southern end. Fossils have been found by BONARELLI and KEIDEL.[1] The present author made a landing in the southern part of the channel, some miles north of Bahia Islas, opposite the big glacier, at the place where a low valley crosses the southern peninsula of the island **(4)**.

The rock is here a black, dense argillitic schist, forming banks of about 30 cm in thickness. The dark schist is rather irregularly interbedded with layers of light gray colour. The jointing is splitty and irregular and the rock is crossed by crush-zones and fissures filled with quartz. In the latter the rock often recalls the more deformed sediments farther inside the mountain-range, for instance at Puerto Tristeza (p. 64).

The banks strike 300°—310°, the dip is 40°—50° W. The general direction of the folding-axes seems to be 310°, the dip is on the place 20° in that direction, which corresponds to the general axial direction in the neighbouring parts of the Central-Cordillera. It may be observed that this direction agrees with that of Canal Gabriel, the latter being 310°.

In several places the rock is cut by almost vertical, dike-like, brecciated zones, running practically perpendicular to the cleavage.

Under the microscope only small grains of felspar and quartz are visible in the dense, turbid ground-mass of the argillitic schist (Sp. 356—358). The rock contains a fairly abundant quantity of elongated, rolled-out bands of carbon, which might be remains of micro-fossils. The general character of the rock is however very unlike the

[1] According to a private communication by Prof. KEIDEL.

radiolaritic schists, found as fragments in the conglomerate described in the foregoing, and occurring in the Central-Cordillera (p. 149), and there is therefore no reason to connect it with the sediments of the last-named. The texture of the rock is in considerable degree influenced by mechanic deformation, though no recrystallizations of importance are visible.

Cabo Expectation (south point of Isla Dawson) **(5).** The rock-ground consists of a rather coarse-grained, greenish-gray sandstone, resembling that of Puerto Nicolas and Puerto Valdez (Sp. 19). The banks lies flat to gently sloping. The strike is about E-W.

Under the microscope the clastic structure proves to be completely unchanged. Mechanical deformations are lacking. The rock contains volcanic material in abundance and recalls in that respect the sediments from the localities named above. The dominating components are well preserved crystal-grains of felspar, pyroxene and hornblende mixed with quartz-fragments. The structure is shown by Fig. 1 Pl. IV.

Plagioclase is greatly altered to zoisite and therefore difficult to determine; generally the composition seems to be comparatively rich in albite. The hornblende is of a brownish-green-coloured, basaltic type. The absorption is γ (dark brownish-green) $> \beta$ (brownish-green) $> \alpha$ (yellowish green). $\gamma : c = 15.^\circ5$. The crystals have a short-prismatic habit with blunt ends. The dom nating forms are the prism and the pinacoids and the basic-plane. The pyroxene is an augite occurring as short-prismatic crystals, shading from colourless to light greenish-yellow. $\gamma : c = 43^\circ$. Quartz occurs comparatively sparsely as irregular crystal-fragments.

Besides these crystal-grains there are also small fragments of a basaltic rock with needle-like plagioclase lests in a vitreous ground-mass, and further an abundance of glass-grains.

The composition of this sandstone is very typical of the »Flüsch»-sediments of the Marginal-Cordillera, particularly its lower horizons. It can with certainty be reckoned to the Cretaceous formation.

Puerto Harris (East-coast of Isla Dawson) **(6).** The principal rock-formation at Puerto Harris is a rather coarse, dark grayish-green sandstone, with interbedded clay-rich layers and also lime-rich varieties.

The sandstone (Sp. 399) consists also here chiefly of dark components: grains of pyroxene and green hornblende and, in smaller quantities, quartz and felspar. The matrix contains a green glauconitic mineral in abundance.

As mentioned earlier (p. 27) the occurrence of plant-fossils belonging to the late Cretaceous period has led to this place being visited by several paleontologists. The newest communication is given by DUELLO HURADO 1928 (18).

THE EAST COAST OF CANAL WHITESIDE AND THE INNER PART OF THE MAIN ISLAND.

The mountains on the east coast of Canal Whiteside consist of Cretaceous sediments similar to those of Dawson and the east coast of the Strait of Magallanes. Also the topographic forms are the same. The region has the typical Marginal-Cordillera character, with even crests rising to 6—700 m above the sea, and between them deep wood-covered valleys with comparatively gently sloping walls. The principal valleys generally run in an E-W-erly direction (for instance the valleys of Rio Grande and Puerto Arthuro).

The rock-ground consists of rather soft sandstones and, particularly farther south, nearer the Central-Cordillera, of clayish slates. In the upper strata of the mountains, behind Yartau and Puerto Arthuro, there are thick layers of conglomerate.

The layers are gently folded, more intensively farther south in the vicinity of the high-metamorphic parts of the Cordillera. In the neighbourhood of Bahia Inutil the position of the layers is rather flat, as far as can be concluded from the coast. In the mountains behind Cabo Yartau the layers slope on the south side to the N, while on the north side of the group the slope is to the S. Behind Estancia Olguita they are almost horizontal, but farther south again become more dislocated, and at Puerto Arthuro the slope is in part almost vertical. The folding is in other words simple, with big anticlines and synclines combined with small thrusts. The style evidently resembles that of the Jura-mountains.

The only place where the author had an opportunity of studying the rock-ground in detail was at Puerto Arthuro **(7).** The rock is here a coarse, almost conglomeratic sandstone, interbedded with carbon-rich slate. Carbonate concretions are very abundant. The beds dip almost vertically, the strike is 260°. In the crest beyond the saw-mill the dip is 30° SSW. Fossils were not found, but probably a more detailed investigation will prove the presence of fossil-remains.

The sediments are strongly brecciated, but not in other respects altered.

The conglomeratic layers contain abundant fragments of black slate, which under the microscope proves to be of the same kind as the slaty schist occurring farther south-east on the north-coast of Seno Almirantazgo and which obviously belongs to the old pre-Cretaceous schists of the Central-Cordillera. They contain the same fossil-remains already described from the pebbles of the conglomerates of Puerto Nicolas and Puerto Valdez. The striking similarity is shown by Fig. 2, Pl. IV. This proves that also

here exists a clear discordance between the sediments of the Marginal-Cordillera and the black schists of the frontpart of the Central-Cordillera (the Buckland formation; *cfr.* p. 61).

We have some observations made by the expedition of the University of Buenos Aires (18) relating to the inner parts of the Marginal-Cordillera farther east of Canal Whiteside. Some short preliminary reports of the result of this expedition have been published by DUELLO HURADO. He reports the occurrence of layers with marine fossils containing *Belanocrinus*: *Belecypria* and others in the locality Despedide **(8)** south of Rio Grande, and determines the layers as being the uppermost Cretaceous or lower Eocene.

He describes another occurrence containing fossils on the international boundary between Argentina and Chile at the boundary point XIX **(9).** Here the rock consists of gray, dense limestone, with the layers striking E-W and dipping about 60° S. It contains *Pélécypodes*, *Belemnides?* and *Tubulostium*. The age is supposed to be Cretaceous but the *etage* is still uncertain.

The Finnish Expedition, which was occupied with phytopalaeontological investigations in the central parts of Tierra del Fuego, also gives some notices about the rock-ground in the tracts of Estáncia Vicuña **(10).** The sediments in this district are mainly very soft dark slate or sandstone (Fig. 7.), with abundant fossil-remains, of which the commonest type can be determined as an *Inoceramus* (Steinmanni?).

The mesozoicum of the Marginal-Cordillera of the Main Island of Tierra del Fuego is after all still very imperfectly known, both from the stratigraphical and tectonical points of view.

Summary.

The general conclusions which can be drawn from the few observations communicated in this chapter may be summarized in the following points:

1. The conglomerate of Puerto San Nicolas (Isla Nassau) and likewise that on the opposite coast of Isla Dawson (Puerto Valdez) are basal-conglomerates, consisting of rocks occurring in the Central- and Coast-Cordillera. They definitively prove the existence of a big disconformity between the Cretaceous (infracretaceous?) layers of the Marginal-Cordillera and the slate-formation of the Central-Cordillera (Seno Almirantazgo and Peninsula Buckland).

2. The sandstone of the south end of Isla Dawson belongs to the same formation as the conglomerates — as far as can be judged from its petrographical composition — and consists chiefly of detrital gravel deriving from the older

rocks of the Cordillera. The black slate of the north coast of Canal Gabriel (Bahia Islas) is possibly to be reckoned to the same group, and would then be identical with the oldest strata of the »Flüsch»-formation. There is, however, no definite evidence that it could not belong to the old slates of Peninsula Buckland.

3. The sandstones of Puerto Arthuro, Canal Whiteside, are separated from the slates in the inner parts of Seno Almirantazgo by a clear disconformity.

B. OBSERVATIONS IN THE CENTRAL-CORDILLERA.

1. Observations in the tracts North-West of the Main Island of Tierra del Fuego.

The South-West-coast of Peninsula Brunswick.

The westernmost part of the Cordillera of Tierra del Fuego visited by the author during his stay in the Magallanes territory was Puerto Gallant **(11)** on the south coast of Peninsula Brunswick. Owing to bad weather at the time, the observations here are very incomplete.

In this part of the Cordillera the mountains are more than 1000 m high and covered with ice, and the forms show almost Alpine character. The direction of the ranges and main-valleys seems to run about NW-SE.

On the shore west of the bay of Puerto Gallant the rock-ground consists of a strongly folded and contorted, gray-coloured micaceous schist with well developed lamellar schistosity. It has been greatly flattened out and deformed during the orogenetic movements. The rock is rich in quartz-veins following the shear-planes, which lie very flat. The general dip of the schistosity is NW-SE, the pitch slopes 5—10° in the direction 330°.

In the mountains north-east of the harbour there occurs a schist very rich in quartz of the same type as described at Bahia Sarmiento in Fjordo Martinez (p. 45). From abt. 150 m above sealevel upward it is displaced by an almost pure, glassy quartzite, which is in a very high degree influenced by movements during the last stage of the crystallization. In different directions it is cut by quartz-veins and is often of an almost brecciated aspect, though the fractures are completely healed and filled out with quartz. The quartzite is occasionally impregnated with pyrite, and in consequence hereof a small mine-cut has been made at this place by gold-miners. In the neighbourhood of the pit the quartzite consists of rounded fragments of pure quartzite, embedded in a matrix of quartzite rich in sericite. It is possible that this rock originally was a conglomerate, but it may also as well be a brecciated zone of the rock. Farther up

the slope there is found at about 200 m above the sea a gray, homogeneous quartzitic schist, occurring as flat-lying banks.

The tectonical conditions of the Puerto Gallant schists are evidently similar to those in the tracts of Fjordo Martinez on the Main Island (see p. 44).

From Puerto Gallant eastward to the neighbourhood of Bahia Andreas the same kind of micaceous schists is found. From here onward the shore cliffs consist of brownish, well-stratified sediments, which at Cabo Holland seem to be rather unmetamorphic. The layers appear to be almost horizontal, this being due to the horizontal position of the folding-axes, which run almost parallel to the shore. East of Cabo Holland follow greenish-gray, compact, eruptive rocks, evidently quartz-porphyries, extending as far as Bahia Snug.

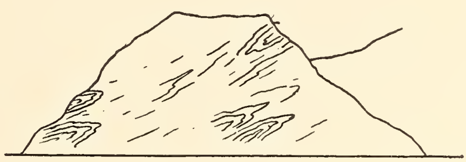


Fig. 9. The folding-style of Cape Froward. The axial-direction of the slate-formation is NW-SE-erly.
Sketched by the author.

At Cabo Froward **(12)** one mets with brownish stratified sediments resembling those of Cabo Holland. They are very strongly folded, forming flat-laying folds overturned toward the NE (*cfr.* fig. 9). The tectonical style indicates an overthrust in this direction with an axial-trend of about SE-NW.

Petrologically the sediments of Cabo Froward are black slates with perfect cleavage.

Isla Clarence.

Only a few places on the north shore of the big Island Clarence, which forms an important section of the central part of the Cordillera, were hitherto at least in some degree geologically known. On the Chilean geological map of the central and eastern part of the surroundings of the Strait of Magellanes, the north-east end of the island, which falls within the map, is marked as consisting of granitic, dioritic and gabbroic rocks, with crystalline schists farther west. The map depicts only a very small part of the island; but nevertheless it gives all the available data regarding the geology of this part of the Cordillera, with the addition of a few observations on some other points along the south coast.

The first data also here have been furnished by DARWIN (17), who points out the occurrence of micaceous schists and quartzitic schists penetrated by greenstone-dikes on the south coast of the island at Canal Magdalena.

Later (1881) the east coast of Isla Clarence was visited by LOVISATO, who made a landing at Bahia Hope, where he collected specimens of micaceous quartzite schist, which partly contained garnet and andalusite (32).

Also the first landing of the present author was made in Bahia Hope **(13).** The bay, which is about 1 km in diameter, is almost round, and surrounded by high, steep mountains 700 to 800 m in height. The place is well sheltered against all winds and is a splendid harbour. On the west slope a small glacier hangs from the mountain-crest, ending at about 600 m above the sea. The bay is a typical glacier-excavation of a kind which is very common along the coasts of Tierra del Fuego.

The subantarctic rain-bush is here uncommonly luxuriant and evidently comparatively old, indicating that the bay already for a long time has been free from the glacier.

Excepting on the shore the rock-ground is covered by the dense vegetation.

About $^1/_2$ km from the shore, in the innermost part of the bay, the author observed a very altered quartz-rich schist, evidently of the kind described by LOVISATO (HYADES 32, p. 192). The rock is rich in mica and strongly folded, with abundant quartz-veins following the planes of the schistosity. The deformation is strong and has given the quartz-veins a ptygmatic aspect. The schistosity is generally almost horizontal and seems to be the result of horizontal sliding movements in the sediments. The axial-direction of the differential-folds is about S or SSW, dipping 15—20°. Here the direction of movement consequently seems to have been from W to E. The dip of the schistosity is gently south-westerly.

The occurrence of garnet and andalusite in the rock indicates the effect of contact-metamorphism and the presence of probably granitic rocks in the neighbourhood. The boulders on the shore also consist partly of granite and diorite.

These rocks were found some km farther north at Bahia Beaubasin **(14)**, where Andean diorites occur.

Beaubasin bay shows the same typical glacier-sculptured form as Bahia Hope. The basin is almost round and very deep, with a narrow, shallow inlet. An open valley measuring about 3 km in length lies at the head of the bay.

At the end of the valley, which for the most part is covered by swamps, there is a small glacier, evidently originating in the same »Firn» as the glacier of Bahia Hope.

The petrographic character of the Andean dioritic rocks is described in the chapter dealing with this rock-group on p. 165.

The author had no opportunity of making any landing on the south coast of Isla Clarence, but seen from the ship the coast gives the following impression: South of Bahia Hope the shore cliffs seem to consist of the same altered type as in the bay itself, generally dipping toward the SW while south of Stokes Inlet the dip in the steep shore cliffs appears to be almost vertical and the strike about WNW-ESE. At the small islands called Islas Labirinto there still occurs schist, dipping 35°-40° S. The cape west of the islands probably consists of diorite or gabbro, which rocks occur along the south coast farther to the west.

From the south coast of Isla Clarence HYADES (32, p. 183—184) gives some data obtained at Bahia Park (Seno Mercurio) and Bahia Eliza (Seno Dyneley) **(15).** At the firstnamed locality he observed a fine-grained, schistose sandstone (*grès*) of greenish-gray colour. The rock seems to be comparatively slightly altered. At the second locality there was found a schistose greenstone evidently belonging to the ophiolites of the Central-Cordillera. The principal components are amphibole and epidote. These rocks probably belong to the same type as later will be described from Bahia Staples on the north coast of the island.

On Isla Camden (32, p. 182) a fine-grained dioritic (granitic?) rock occurs, probably a contact variety of the Andean diorites.

Seno Staples (Staples Sound) **(16).** On the north coast of Isla Clarence the Finnish expedition visited the inner part of Seno Staples, one of the fjord-like narrow bays opposite Seno Mercurio. This sector of the island is comparatively low, and crossed from north to south by a broad valley. Like most of the old valleys of the Central-Cordillera which have not been influenced by a more intense erosion during the later stages of the development of the Cordillera, the relief of the valley-floor is very uneven, with rounded hills with steep slopes and small flat plains between. The difference in altitude is 100 to 200 m. The deepest part of the big valley is filled up by a fairly big lake, extending southward to some km from Seno Mercurio (Fig. 10). This lake the expedition named Lago Laina. Strong glacial action accounts for the typical character of the valley relief.

The vegetation is partly open swamp, partly, more especially on the mountain-slopes, luxuriant rain-bush. The surrounding mountain-ridges are

comparatively low and rise only to heights of some hundred metres. Not till the tracts of Bahia Hope and Bahia Beaubasin do they again become higher and partly glaciated.

Farther west from the valley of Seno Staples rises a long mountain-ridge with snowpeaks. It was named Sierra Wilhelm Ramsay in memory of the late professor of geology of the University of Helsingfors, Dr. WILHELM RAMSAY, who was one of the most active patrons of the expedition (Fig. 10).

The rock-ground in the tracts of Seno Staples consists partly of highly deformed and lamellated schists, partly of altered greenstones, with a general dip towards the west.

Around the fjord-end the shore-cliffs consist of greenish-gray chlorite-sericite schists. They are highly sheared with perfect cleavage, the cleavage-planes generally being filled with chlorite. The deformation is strong and shows an unmistakable similarity with Alpine central-schists. Farther north, at the inlet of the narrows, the schists seem to become more quartzitic, and prove under the microscope to be a metamorphosed sandstone or graywacke. Southward the chloritic schists predominate. The schists are traversed in great abundance by quartz-veins, usually running in direction 70°. The dip is generally 30—40° S, in part flatter still. The pitch, which is poorly developed in consequence of the strong lamellation, points usually north to south or NNE-SSW, in other words almost parallel with the direction of the fjord.

South of Seno Staples, around the north end of Lago Laina, the bedrock is composed of coarse-grained greenstone of gabbroidic aspect. For the most part the rock is strongly metamorphosed, with chlorite and talc as main components, but occasionally also the original structure is plainly visible. In some places the rock is porphyric with phenocrysts of altered pyroxene and amphibole. These meta-gabbros and meta-porphyrites resemble similar rocks found by the author in several parts of the Central-Cordillera farther east, where they occurred infolded with the metamorphic sedimentary schists (*e.g.* Fjordo Martinez, Lapataia, Monte Olivia). They are probably to be interpreted as ophiolitic intrusions, intruded contemporaneously with earlier stages of the main-folding of the Central-Cordillera. They have in some places reached the surface of the earth, thus forming extrusive beds, and this has evidently been the case at Isla Clarence, where the greenstone seems to occur in rather thick layers, interstratified with tuffitic schists.

In the field the brownish-red weathering of the greenstone renders it easily distinguishable from the sediments.

Fig. 10. Sierra Wilhelm Ramsay on Isla Clarence. In the foreground Lago Laina; beyond the lake a bay of Seno Mercurio is visible.
Photo E. H. K.

Fig. 11. Bahia Plüschow seen from the mountains E of the fjord. In the foreground the steep southerly dip of the quartzitic schists is visible. Looking west.
Photo E. H. K.

Microscopic investigation of the rock-types of Bahia Hope and Seno Staples proves that the rocks have undergone a recrystallization in connection with a strong mylonitization. The following specimens give the petrographical character of the most typical rocks of the localities.

Sp. 20. *Quartz-biotite schist,* Bahia Hope, Isla Clarence.

The rock is megascopically rather fine-grained, strongly schistose, with intense differential-folding. Of the mineral-components only lustrous flakes of mica and white quartz are visible, the last-named frequently forming veinlets.

Under the microscope, the rock appears to consist mainly of granulated quartz and brown biotite. Also sericite is present in abundance, but chlorite is almost absent. Epidote occurs only as a few big grains with high bi-refraction (pistazite). They have evidently crystallized earlier than the latest shear-movements in the rock. Magnetite is sparingly present. The rolling out and mylonitization is strong. The shear-planes are sometimes filled with flakes of talc. The abundance of biotite may in part depend on contact-influence by the Andean diorites at the place.

Sp. 289. *Chlorite schist,* Seno Staples, Isla Clarence.

The extremely strong mylonitization appears already megascopically in the perfect cleavage of the dark green, soft schist, but is still more plainly visible under the microscope. The main mass of the rock consists of a very fine-grained parallel-striated matrix, consisting of quartz, chlorite and epidote. The mineral-grains can be distinguished only when strongly magnified. This fine-crushed mass is traversed by shear-zones, containing chlorite in coarse crystals, and forming very consequently parallel-orientated flakes and small rounded epidote-grains in bands, following the same direction. The crystallization was obviously contemporaneous with the shear-movements and no recrystallization has occurred after the shear-movements ended. Quartz-grains of bigger size are completely crushed up and rolled out to thin lenses. Leucoxene is sometimes seen as a dull pigment. A few pyrite-cubes can be observed as a later crystallization.

Sp. 289—294. *Ophiolitic greenstone.* Bahia Staples, Isla Clarence.

The greenstones are partly rolled out and schistose, but never in so high a degree as the underlying rocks already described. In several cases the original texture is comparatively well preserved. The composition is: plagioclase, epidote, actinolite, chlorite, titanite and ilmenite. The plagioclase is albitic and the rock has a typically prasinitic character. Evidently the principal femic mineral originally was an augite, but this mineral is altered into epidote and chlorite. The epidote is light yellow, with rather strong pleochroism. It is obviously fairly rich in iron. Also titanite is originated at the same alteration, indicating that the primary component was a titan-augite. The ore-mineral is for the most part altered into leucoxene. — The more deformed varieties have mainly the same mineralogical composition, but generally contain more chlorite.

About one km south of the end of Seno Staples the author found boulders of a dark-coloured rock of sedimentary origin, which under the microscope appears to be a tuffite.

Sp. 295. *Tuffite,* Seno Staples, Isla Clarence.

The rock consists in part of crystal-fragments of quartz, plagioclase and altered potash felspar in a fine-clastic ground-mass, greatly resembling that of the tuffs belonging to the quartz-porphyries of Almirantazgo, etc. There are also irregular inclusions of a dark carbon-rich schist, greatly resembling the phtanitic schists of the Monte Buckland series

(*cfr.* p. 61). The rock contains fairly well preserved remains of radiolarias, a fact which proves that it really belongs to the same formation as the Almirantazgo porphyries. Evidently, we here have a boulder deriving from the undermost strata of the series named above.

This observation is of importance, in showing that also sediments of the upper group of the central schists (*cfr.* p. 207) possibly occur on Isla Clarence (Bahia Park?). The rock in question might possibly derive from the mountains farther to the south-west.

2. Observations in the Western Parts of the Main Island (Isla Grande) of Tierra del Fuego.

General Remarks.

All the expeditions which have hitherto carried out geological investigations on the Main Island have with few exceptions worked along the south coast in the eastern parts of the island. Only in the tracts of Seno Almirantazgo has there been more field-work. The wide fjord-area inside Seno Keates has remained completely unknown from a geological point of view.

At Canal Magdalena, on the west coast of Peninsula Sarmiento, Lovisato made some observations on the coast below Monte Sarmiento, which, in spite of their incompleteness, are of importance, as giving the only data available regarding the petrological composition of the most famous summit of the Western Cordillera (*cfr.* Hyades, 32).

The sector of the Cordillera here in question affords in many respects better opportunities of studying the structure of the mountain chain than do the easterly parts; this being a consequence of the long fjords which extend to the innermost kernel of the range, and in certain cases cut through the whole of the central chain.

The present author had an opportunity to study the geological conditions along the shores of Fjordo de Agostini and Fjordo Martinez, the two hydrographical main-elements of the area, while an excursion was made also to Seno Almirantazgo.

Fjordo Almirante Martinez.

Fjordo Almirante Martinez or Fjordo Martinez, the more westerly of the two big fjord-arms, forms the continuation of Seno Keates, in a straight southerly direction. Its length is about 30 km, and the average breadth about 2 km. The principal direction is north to south. Fjordo Martinez is morphologically a typical cross-valley, cutting the axial-trend of the cordillera-folding almost at right angles. The south end of the fjord is separated from the south coast by a narrow, comparatively low isthmus only 4—5 km broad.

Both coasts of Fjordo Martinez are steep and high, exceeding generally 1000 m in height. The summits are between 1500 and 2000 m. The glaciation is very strong. Up to about 900 m above the sea the mountains are ice-covered, and numerous glaciers, eight of which are of a large size, flow down to the coast.

The topography of the valley is characterized by the greater steepness of the western coast and the more gentle slope of the eastern side. This is evidently attributable to the structure of the rock-ground, the dip of the schistosity mainly being south-westerly, in the direction away from the western shore (*cfr.* Fig. 12). The mountain-wall of the latter is only in a few places cut by narrow, glacier-sculptured gorges, of which the three biggest end in Bahia Sarmiento and in the big bay on the west-side close to the fjord-end.

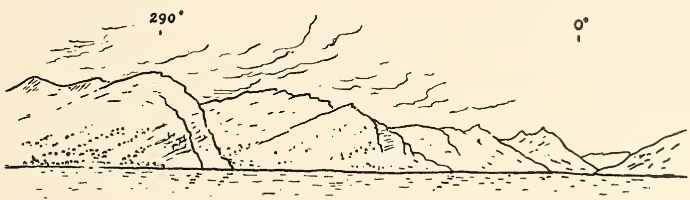


Fig. 12. The west coast of Fjordo Martinez seen from the southern end of the fjord. The schistosity dips in a southerly to south-westerly direction. Sketch by the author.

The few valleys on the east side are also short and steep. Only one is bigger and forms a branch-arm (Bahia Plüschow), some kilometres in length, not far from the south end of Fjordo Martinez. It is a beautiful fjordlet, surrounded by crests about 1000 m high (Fig. 11). — In this connection it may be pointed out, that the English and American charts erroneously show a second deep bay north of Bahia Plüschow. De Agostini's map (1) gives a correct representation of the coastline.

The rock-ground of the coasts of Fjordo Martinez consists of highly altered schists, for the most part quartzitic or micaceous schists, often interbedded with greenstone-layers. At the south end of the bay the greenstones predominate. Except in the southernmost part of the area the schistosity is very flat-lying, almost horizontal.

The following localities were examined more in detail:

B a h i a S a r m i e n t o **(17)**. The two-branched bay provides a roomy, well sheltered harbour, surrounded by steep mountain-walls, which rise almost vertically to about 260 m. At that height there is frequently a shelf, which is particularly well developed on the mountain in the centre of the bay, being

several hundred metres broad, and almost horizontal. On the shelf there is a small lake formed by the meltwater from the glaciers above. — Two big glaciers end on the valley-floor of Bahia Sarmiento; one in the north-west, the other in the south west-corner. The marginal-moraine of the latter dams up a fairly big lake. The valley-floor is mostly covered with swamps and the sparse forest-vegetation is restricted to very low but dense brush-wood. Several streamlets flow out in the bay; the biggest at the north-west end.

At the point north of the inlet t h e r o c k-g r o u n d consists of light-gray, micaceous schists highly rolled out and deformed, with very pronounced shear-structure and flat-stressed miniature folds. The axial-direction of the latter generally runs about 310°—330°. The dip both of the schistosity and the folding axes is also generally flat. The rock contains an abundance of white quartz-veins. Higher up the mountain (abt. 150 m) the quartz-percentage increases and it grades into a sericitic quartzite-schist. The mechanical deformation is not limited to the lamellar-schistosity and a »sugar-grain-like» crush-structure, but the rock is also traversed by a network of fractures resulting in a complete brecciation. The fractures of this breccia are nevertheless healed with white quartz. The brecciation crosses the original lamellar schistosity and seems therefore to be at least in some degree younger than the latter. It resembles, as already pointed out, (p. 39) the brecciation in the quartzite-schists at Puerto Gallant, on the north shore of the Strait of Magallanes. It may be observed that the rock was never completely crushed at the brecciation; the rock-fragments have not been moved from their original position. The brecciation has evidently been caused by strong pressure on the rock-complex, which has given rise to an intense fissuring, but which has not changed the general schistosity of the rock-fragments. The filling up with quartz has probably been contemporaneous with the opening of the fractures. Fig. 4, Pl. VII, shows a quartzite specimen, brecciated in the way described above.

In the mountain-slope between the two glaciers quartzitic schist is found on the shore, higher up follows micaceous schist with layers of strongly altered greenstone of ophiolitic character. The series is crossed by younger dikes, cutting the schistosity. They also have been influenced by mechanic deformation, but the schistosity is less conspicuous than in the country-rock.

These observations indicate that in this part of the Cordillera there has been a repetition of the folding movements in the rocks.

The microscopic investigation of the greenstones of Bahia Sarmiento gives the following result:

Sp. 306. *Ophiolitic greenstone.* Bahia Sarmiento, Fjordo Martinez (Microphotograph Fig. 2, Pl. VII).

Megascopically the rock is medium-grained, dark greenish-gray and porphyric with small phenocrysts of dark greenish pyroxene. The mechanic deformation is visible already to the naked eye. The original structure is greatly destroyed by the metamorphism which also has altered the original mineralogical composition. The composition is: augite (phenocrysts), plagioclase, uralitic amphibole, chlorite, epidote, titanite and ilmenite.

The a u g i t e-crystals have in high degree lost their original shape, partly due to the secondary alteration, partly because they were crystallized early and have later been resorbed by the residual melt. The edges are therefore always very uneven and rugged. The mineral is almost colourless, and is composed of very thin twinning lamellae, which cause incomplete extinction. The optic orientation is mainly $\gamma : c = 40^\circ$. Included in the big augite-crystals is an abundance of poikilitic plagioclase-grains. — The outer parts of the pyroxene crystals are generally altered into light-greenish uralite.

The m a t r i x consists mainly of a nematoblastic mass of needle-shaped minerals, among which a light-green actinolitic amphibole predominates. C h l o r i t e occurs as felty aggregate. E p i d o t e occurs in two different types, of which one replaces the augite. It has a rather weak bi-refraction and is colourless. The other is crystallized later and often occurs in clear, idiomorphic crystals, growing around the former type. $\beta : c = 21^\circ, 5$. The color is greenish-yellow. The p l a g i o c l a s e is sometimes well preserved, sometimes altered to epidote, etc (abt. 35 % An).

The crystallization of the rock evidently began at a rather high temperature, with augite. Then — in connection with the folding and overthrusting — the rock was brought up to higher zones, and the matrix crystallized with low-temperature minerals (prasinitic).

Sp. 310. *Greenstone-schist.* Dike crossing the foregoing rock (Microphotograph Fig. 1, Pl. VII).

The rock is megascopically strongly schistose. No primary features are visible. The composition is: light-yellowish fibrous amphibole, zoisite, quartz, serpentine and leucoxene. Primary felspar is entirely lacking.

The schists of sedimentary origin offer petrologically not very much in addition to the observations in the field. The quartzitic schists (Sp. 244, Fig. 4, Pl. VII) are seen under the microscope very strongly mylonitized, and as already the conditions in the field made probable, the deformation extended over a rather long time, coinciding with several stages of mylonitization. One part of the rock has evidently escaped the action of the latest movement. It forms rather less deformed fragments, surrounded by completely granulated, often sericite-bearing shear-zones. The quartz of the fragments is also granulated, but afterwards newcrystallized in grains of bigger size. The latest movements have only given rise to an undulation in the mineral.

The sericite schists (quartzphyllite) (Fig. 3, Pl. VII) are mainly composed of quartz, biotite (greenish-brown) and sericite and abundant small grains of epidote. Also felspar, particularly albitic plagioclase, but also altered potash-felspar, is present. The structure is strongly influenced by the movements and traversed by shear-planes along which foremost the dark minerals have been deposited. The re-crystallization is obviously in high degree ruled by the deformation, and broadly speaking contemporaneous with the last-named (Sp. 303). A striking feature in the sericitic schists of the place, which evidently depends on the chemical composition, is the absence of chlorite. — In spite of the alteration the rock sometimes shows traces of the original clastic structure, in the form of rounded grains of quartz and felspar.

The South Arm of Fjordo Martinez **(18).** The southernmost end of Fjordo Martinez is a narrow bay, about 3 km long. The mountains around this part of the fjord are comparatively low and soft, and the general character of the landscape shows that this tract is already situated on the south side of the main ridge of the Cordillera.

From the fjord-end, the author made a landtraverse along the valley which forms a continuation of the fjord and reaches to the opposite coast. The height of land between Fjordo Martinez and the south coast is here only about 250 m above the sea-level and there is therefore no difficulty in crossing the Cordillera, the more so as the valley is open and almost without forest-vegetation. The ground is covered with thick, hard swamps, which afford easy walking ground.

Behind the watershed there lie two small lakes, the first about 2 km, the second about 3.5 km from the fjord-end. They flow out in a southerly direction. A third lake is situated farther to the east, behind a small ridge running parallel to the valley (*cfr.* Figs. 13 and 14).

The rock-ground. On the shore of the South Arm the rock-ground consists of fine-grained greenstone, forming thick (30—40 cm) banks, sloping about 60° S. The weathered surface is light-greenish and greatly resembles a fine-grained quartzite, also in the hand-specimen. Farther south quartzitic layers alternate with the greenstone. The former are pure white and granulated, and when weathered disintegrate easily to fine white powder.

In the vicinity of the watershed greenstones of obviously supercrustal character are found. These might be strongly metamorphosed and deformed lavas with interbedded tuffs. Traces of pillow structure are often visible, though highly stressed and partly rolled out to thin lamellae. Moreover, these are folded into numerous differential-folds, with the axial-direction running mainly 100° (axial-dip 40°). The average axial-direction of the whole complex

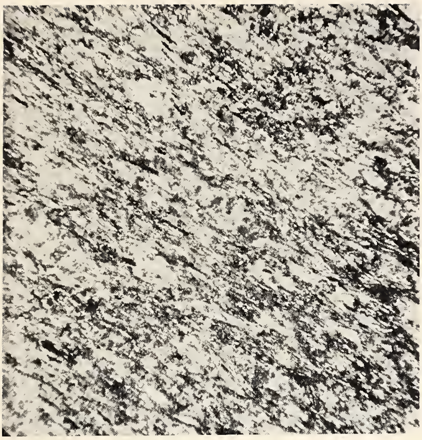
EXPLANATION OF PLATE VII.

Fig. 1. Chlorite-sericite shcist. Bahia Sarmiento, Fjordo Martinez. The mineral components are:chlorite, epidote, mica, albite and plagioclase. Magn. 15 ×, Nic. ∥.

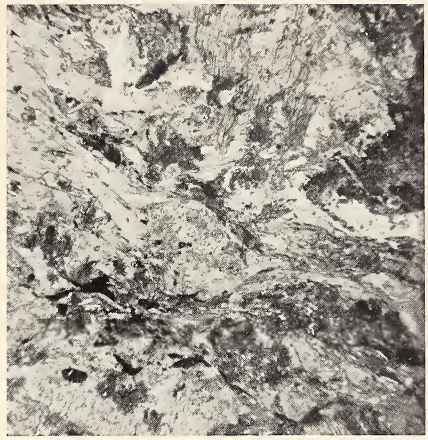
Fig. 2. Ophiolitic greenstone (prasinite). Bahia Sarmiento. The mineral-components are actinolitic amphibole, mica, epidote, albite, quartz and titanite. Magn. 15 ×, Nic. ∥.

Fig. 3. Sericite-schist with riffling and differential folding on the shear-planes. Bahia Sarmiento.

Fig. 4. Brecciated and recrystallized sericite-quartzite. Bahia Sarmiento.

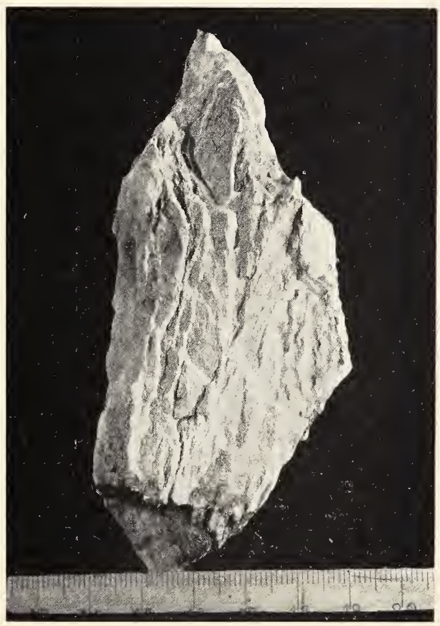


1



2

3



4

Fig. 13. View of the watershed south of Fjordo Martinez seen from the mountain on the SE shore of Bahia Plüschow. In the foreground quartzite-schist, in the valley behind metamorphic greenstones.
Photo E. H. K.

Fig. 14. The height of land between Fjordo Martinez and the south coast of Tierra del Fuego. The rock-ground consists mainly of metamorphic greenstone.
Photo E. H. K.

seems to be about E-W, with varying inclination. — On shear planes rather big crystals of magnetite and hornblende are often seen.

The greenstone schists are in several places cut by younger, less deformed dikes.

In addition, granitic dikes were observed at several places in the valley, the number increasing farther to the south, running in the direction E-W. They evidently derive from the granitic rocks of the Coast-Cordillera, and they have as a matter of fact not been observed anywhere in the northern parts of the mountain-ridge. They consist of a very light-coloured, medium-grained, aplitic rock, which is rather perceptibly influenced by mechanical deformation.

On the south coast the mountains are probably composed of dioritic rocks.

The greenstone-schist formation south of Fjordo Martinez differs from the schists earlier described from the northern parts of the fjord, as a consequence of the different character of the folding-style. The position of the layers is more or less steep, and the folds frequently are almost isoclinal in position. Also the degree of recrystallization is generally greater, though on the other hand the lamellar schistosity is less conspicuous.

The petrological character of the rocks will be seen from the following descriptions:

Sp. 319. *Prasinitic greenstone.* South end of Fjordo Martinez.

The rock is megascopically fine-grained, light grayish-green, without predominant schistosity. Under the microscope there appears a very fine-grained ground-mass, of even-grained, almost micrograninitic structure, with vague signs of parallel-orientation, particularly of the dark components. The test with gypsum-lamellae, however, shows that there is a distinct orientated crystallization, with the axis of greater refraction on an average running perpendicular to the direction of deformation. The mineral-composition is: albite, epidote, chlorite and in small quantities quartz, pyrite, magnetite and calcite. The size of the components is almost equal; the boundaries are rounded and unsharp. Albite occurs somewhat more abundantly than the other components.

In the fine-grained ground-mass there occur solitary idiomorphic phenocrysts of albite, with a size of 1—2 mm in diameter. These are slightly altered into epidote and sericite.

Sp. 313. *Chlorite-schist* (supercrustal?). About 2 km from the south end of Fjordo Martinez (Microphotograph Fig. 6, Pl. IX).

The rock represents a more deformed type within the same greenschist-complex as the foregoing. The rock is megascopically dark greenish, distinctly schistose, sometimes with idioblastic grains of magnetite visible to the naked eye.

Under the microscope the mineralogical composition appears to be mainly chlorite, albite and quartz, with epidote more subordinated. Magnetite, titanite and pyrite are the principal accessory components. The parallel-structure is very beautifully developed with the chlorite seams orientated along the moving-planes, and the plagioclase and quartz completely crushed up. Nothing is left of the original structure nor probably also of the original mineral-constituents.

The greenstones described above correspond as to mineralogical development to the p r a s i n i t e s of the Alpine geologists and are also genetically obviously of a similar origin. There are in the same locality also basic schists which are developed in the amphibolite facies (*cfr.* e.g. VOGT 62, ESKOLA 19,20, VEG 63, SCHEUMANN etc.) and represent rocks which have been altered at higher temperature. The following specimen is of this type.

EXPLANATION TO PLATE IX.

Fig. 1. Garnet-epidote quartzite. The mica- and epidote-rich shear-planes bend around the big garnet-idioblasts. In the right hand upper corner layers of pure quartzite. The garnet is for the most part altered to chlorite. Bahia Plüschow, South end of Fjordo Martinez. Magn. 24 ×. Nic. ||.

Fig. 2. Quartzite schist with elongated, undulose quartz-grains orientated in accordance with the deformation. The dark bands are garnet-rich layers. Bahia Plüschow. Magn. 15 ×, Nic. +.

Fig. 3. Glaucophane-garnet schist. Big, idioblastic glaucophane-crystals bordered by calcite. They are in some degree resorbed and rich in poikilitic inclusions of quartz. Other constituents are epidote, chlorite, biotite, muscovite and quartz. Bahia Plüschow. Magn. 24. Nic. ×.

Fig. 4. Zoisite-chlorite prasinite. The min. components are mainly colourless clinozoisite, chlorite, quartz and albite. Ophiolitic layer between quartzite-schists. Bahia Plüschow. Magn. 24 ×. Nic. ||.

Fig. 5. Greenstone dike penetrating the greenschist formation south of Fjordo Martinez. The rock consists of idiomorphic, blunt-ended hornblende-crystals, plagioclase, small quantities of quartz, epidote, mica etc. It possibly belongs to the Andean diorite series. 2 km S of the S end of Fjordo Martinez. Magn. 24 ×. Nic. ||.

Fig. 6. Chlorite schist with very strong deformation-structure and mylonitization. The dark minerals are chlorite and finegrained epidote. The light coloured are quartz and abilite. S end of Seno Staples. Magn. 24 ×. Nic. ||.

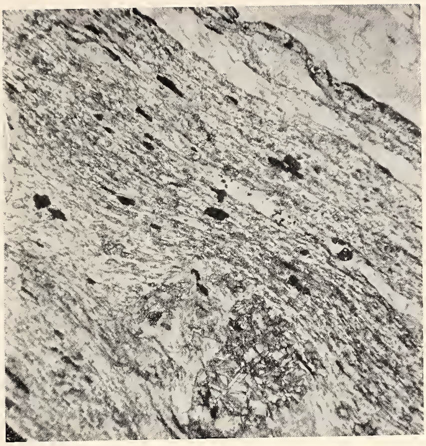
EXPLANATION TO PLATE X.

Fig. 1. Folded quartzite schist. Bahia Plüschow, South end of Fjordo Martinez. About $^1/_2$ nat size.

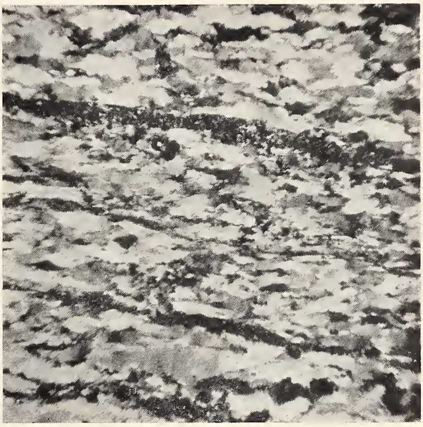
Fig. 2. Glaucophane-garnet schist. Black elongated crystals of glaucophane and round garnet-grains in a light-coloured ground-mass. About $^1/_2$ of natural size. Bahia Plüschow.

Fig. 3. Garnet-bearing quartzite schist with perfect cleavage. The rock is completely crystallized and shows no mylonitic structure. (*cfr.* Fig. 4). Bahia Plüschow.

Fig. 4. Mylonitic quartzite with sugargrain-like structure. The last deformation was later than the recrystallization. Boulder from Puerto Garibaldi on the south coast of the Main Island of Tierra del Fuego.

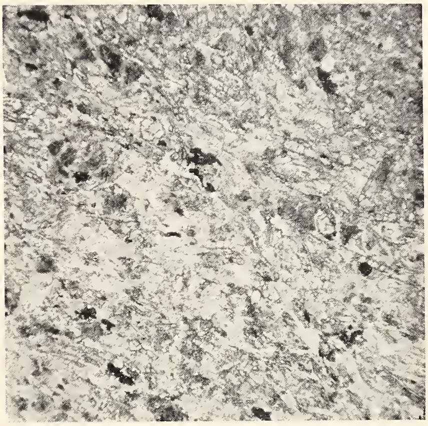


1

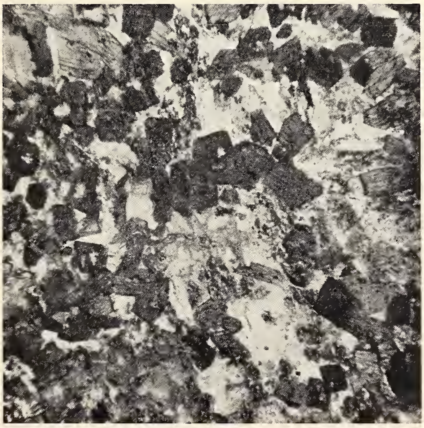


2

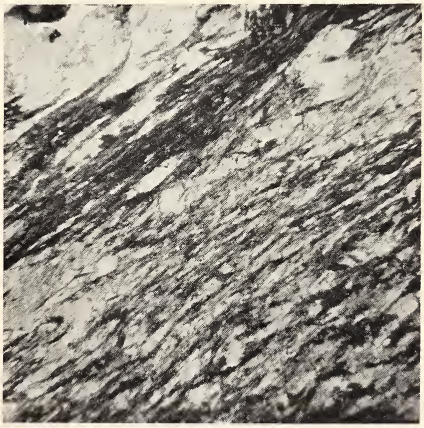
3



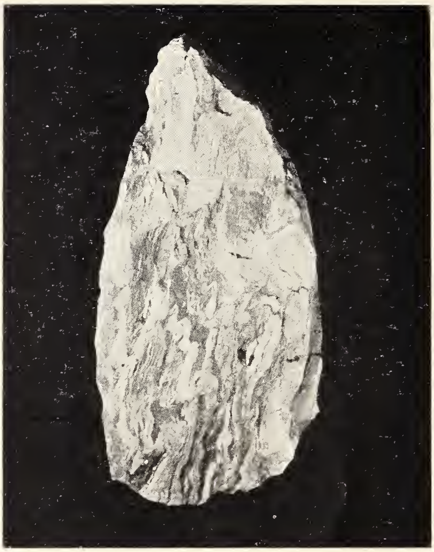
4



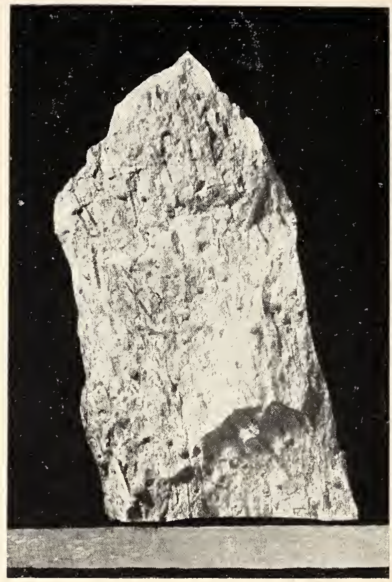
5



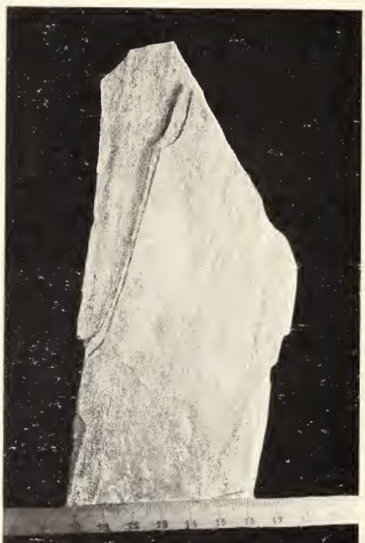
6



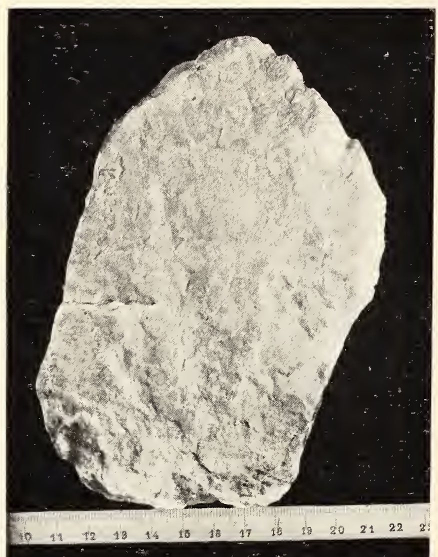
1



2



3



4

Sp. 314. *Amphibolite,* about 2 km S of Seno Martinez (Fig. 5, Pl. IX).

The rock is dark greenish-gray, medium-grained with megascopically visible black amphibole-crystals. The parallel-structure is not conspicuous. The mineralogical composition is about the same as that of the foregoing, but the minerals are better individualized.

The dominating constituent is a brownish-green hornblende, occurring as remarkable short-prismatic, blunt-ended, sharply idiomorphic crystals of about 0.3—0.4 mm diameter. The mineral forms at least 60 % of the rock. The absorption is the normal one of green hornblende, *viz.* $\gamma : c = 15°$. The matrix between the hornblende-crystals consists of plagioclase, chlorite, epidote, calcite and mica and also quartz in abundance. The plagioclase is for the most part altered into chlorite and calcite.

These greenstones are penetrated by a light-greenish dike, the composition of which resembles the prasinite described above, and they are consequently very different from the amphibolitic greenstones (Sp. 312,). The rock is fine-grained, lightgreenish. The mineral-composition is mainly: epidote, chlorite, albite, sericite, and quartz. The parallel-structure is not conspicuous, though clearly visible as an orientated crystallization. The rock is porphyric, but the original phenocrysts of augite and plagioclase are completely altered into chlorite and epidote and are often difficult to distinguish from the groundmass.

The dike seems to indicate that the prasinitic greenstone of the South Arm is a little younger than the schistose greenstones farther south, and that there may be at least a slight disconformity between them. The observations are, however, too few to solve the question definitely.

Bahia Plüschow **(19).** The third locality where the author had an opportunity of making field-observations was Bahia Plüschow. The place was so named by the Finnish Expedition in honour of the courageous German airman GUNTER PLÜSCHOW, who was the first to cross the Cordillera of Tierra del Fuego by aeroplane and who lost his life in an attempt to explore the mountains west of Lago Argentina.

The beautiful fjordlet is surrounded by steep cliffs, except at the innermost end, where a small valley opens. It continues at least 10—15 km farther eastward from the end of the fjordlet. From the mountains on the south-side a rather big lake is visible 5—6 km from the coast (Fig. 11, p. VI).

The author climbed the mountain rising from the narrow crest, which separates the bay from a glacier-covered gorge on its south side.

The rock-ground at this place consists of strongly altered schists, which in many respects differ from those of the localities farther north (Bahia Sarmiento). They are still more deformed and recrystallized. The dominating rock is a quartzitic schist, with mica-rich layers; but also greenstone in rather thin beds occurs in abundance. The layers dip abruptly to the south, and are in general comparatively steep. The folding-axis is almost horizontal, east-westerly.

The sequence of layering in the mountain-slope may be said to be as follows:

On the shore, at the foot of the mountain-slope, a strongly deformed quartzitic schist is found occasionally containing an abundance of mica and other dark components, *i.a.* garnet in varying quantities. In some places the rock becomes rather coarse-grained, with big porphyroblastic crystals of red garnet and dark, long-prismatic amphibole, and has the appearance of »Kerbschiefer» (Fig. 2, Pl. X). — The strike is 30°, the dip gently westerly. The pitch points flat eastward.

100 m above the sea. Quartzitic schist, gradually changing higher up into almost pure quartzite. Strike 30°, dip westerly.

300 m. Fine-grained ophiolitic greenstone. The schistosity shows an angular disconformity with the underlying quartzite, probably due to tectonic movements. Strike 75°, dip steep southerly.

340 m. The same greenstone, followed by layers of mica-schists with interstratified beds of igneous origin.

500 m. Flat-lying layers of schistose quartzite. The pitch runs 75°, dipping 20°. The aspect of this rock is shown on Fig. 3, Pl. X.

The crest of the mountain, 800 m above the sealevel, is chiefly composed of pure quartzite, with interstratified thin layers of micaceous schist. The rock splits easily into regular flakes, of about 1—2 cm thickness. It is beautifully folded into small, flatlying folds, overturned towards the north (Fig. 1, Pl. X). The axial-direction runs 285°, and is almost horizontal. The deformation and particularly the degree of recrystallization is much less conspicuous than in the lower strata of the mountain. Garnet in small, often microscopic crystals, arranged along moving planes is, however, also here a common constituent.

The quartzite is occasionally cut by basic dikes, which are undeformed, and are younger than the folding. They probably belong to the latest intrusions in connection with the folding-movements, *i.e.* derive from the magma of the Andean diorites. In addition, the author observed rather thick light-coloured dikes, which may be identical with the granitic dikes in the region south of the South Arm (p. 196).

Microscopic examination of the hand-specimens gives the following result:

Sp. 321, 328. *Garnet quartzite-schist.* The shore of Bahia Plüschow (Microphotograph Fig. 1, Pl. IX).

Megascopically the rock is rather fine-grained, and contains dark components in abundance. The microscopic texture is somewhat fibrous, due to the well developed pitch. The principal mineral-constituents are: quartz, garnet, sericite, biotite and chlorite. The structure is idioblastic with comparatively big (abt. 2 cm) crystals of garnet embedded in a more fine-grained ground-mass. The schistosity usually bends around the garnets, showing that they are partly older or contemporaneous with the deformation. T h e

g a r n e t is corroded and always surrounded by a rim of chlorite, sometimes even being completely chloritized. Within the mineral-grains there is often seen a weak birefraction with a small optic angle and of positive character. Besides, it contains poikilitic inclusions of quartz and felspar. Small grains of z i r c o n and t o u r m a l i n e are frequently found as accessory components. The rock is partly stratified in layers of crushed quartz, and more mica-rich strata.

The idioblastic crystals of garnet seem to be a little older than the latest movement in the rock, and the youngest shear-zones bend around the grains, which frequently are slightly crushed and optically anomalous, as already mentioned. The latest mineralization, the chloritization of the garnet, has, however, taken place later than the last movements. Otherwise the completely preserved crystal form of the altered garnets could hardly be explained. — The alteration of the original rock has consequently gone through several stages. The first and most important was the recrystallization of the quartz and felspar and the origination of mica and garnet, which coincides with the main-deformation of the rock. The chlorite and sericite, etc. were formed later, during and partly also after the finishing of the last movements. This sequence is found in all the rocks in the southernmost sector in the Cordillera investigated by the author.

Sp. 326. *Quartzite schist.* The crest of the mountain on the south-east shore of Bahia Plüschow, Fjordo Martinez (Microphotograph Fig. 2, Pl. IX).

The rock is light-yellowish-gray in colour, and has a perfect cleavage in thin (1 cm) flakes. To the naked eye it appears to consist of almost pure quartz. Under the microscope the rock shows a beautiful orientated crystallization of the quartz-grains[1], which are all elongated nearly parallel with the direction ε'. The recrystallization is almost complete, there is very little mylonitization to be seen. Only a slight undulation indicates a rupture perpendicular to the schistosity plane. The aspect of the rock is seen on the microphotogram Fig. 2, Pl. IX. Besides the quartz, the rock contains only small quantities of sericite and very fine-grained garnet orientated like strings of beads, parallel with the general shear-direction of the rock.

The quartzite of Bahia Plüschow is interesting when compared with the quartzite-schists described from *e.g.* Bahia Sarmiento, which, like the other rocks in the inner parts of the Cordillera, are strongly mylonitized and only incompletely recrystallized (*cfr.* Fig. 3 and Fig. 4, Pl. X).

Sp. 329. *Glaucophane-garnet schist.* E shore of Bahia Plüschow (Microphotograph Fig. 3, Pl. IX).

This interesting schist is a light-coloured, medium-grained rock with idioblastic grains of red garnet and elongated, almost black amphibole crystals. The schistosity is not very strong in the hand-specimen. The mineralogical composition is: garnet, alkaline amphibole, quartz, sericite, biotite, chlorite, calcite, apatite and magnetite. The structure of the rock is shown on the microphotogram and the megascopic aspect on Fig. 2, Pl. X.

The a m p h i b o l e of the rock is an alkaline variety of the kind known from the metamorphic schists of the Alps, from California and other localities. The crystals are long-prismatic, up to 1 cm in length and comparatively thick. The edges are always resorbed and porous, and the ends fibrated. The optical properties are: α (azure-blue) $>$ β (bluish-green) $>$ γ (light greenish-yellow), $\gamma : c = 13°$.

[1] A structural analysis according to the methods of SANDER has been carried out by Mr. TH. SAHLSTEIN, and will be published later on.

The crystals are surrounded by reaction-rims consisting of a greenish, thread-like mineral with a high index of refraction (talc?), and chlorite, also mica, is generally present. Very often the crystals are also covered by a shale of calcite. Under the microscope the g a r n e t occurs as reddish crystals, with inclusions of poikilitic quartz and calcite. The mineral is in some degree crushed up, but clear and unaltered. C a l c i t e also occurs as independent elongated grains with blunted edges. The other constituents form the fine-grained matrix of the rock, which is mainly composed of quartz and biotite. The latter sometimes occurs as big flakes.

Originally, the rock evidently was a carbonate-rich sandstone belonging to the quartzite formation. The mineralogical composition has probably partly been originated under the influence of contact-metamorphic reactions, and is partly due to the strong shear-movements in the rock. The crystallization in connection with the last-named obviously has passed through several stages, under different physico-chemical conditions. The first-formed minerals — amphibole — have later been unstable and partly altered into low-temperature components (*cfr.* p. 147).

To the same formation belongs also the following greenstone, which has an aspect somewhat different to that of the greenstones described above.

Sp. 322. *Zoisite-chlorite prasinite,* E end of the crest of the Mountain, E of Bahia Plücshow (Microphotogram Fig. 4, Pl. IX).

The rock is megascopically of a grayish-green colour, rather fine-grained and decidedly schistose. The structure is nematoblastic. The composition is: zoisite, actinolite, chlorite, quartz, titanite and Ab-rich plagioclase. The dominating mineral is the almost colourless z o i s i t e in comparatively big prismatic crystals, differing from the epidotes in the rocks described before by the very low bi-refraction. The interference-colours are generally ultra-blue. The axial-plane is parallel with the c-axis. The mineral seems consequently be very poor in iron. The amphibole is of weak pleochroism: γ (light-green) $> \beta$ (yellowish-green) $> \alpha$ (colourless), $\gamma : c = 10°$. Light-greenish c h l o r i t e forms the matrix between the zoisite and amphibole-grains.

The metamorphic rocks around the southern part of Fjordo Martinez represent a metamorphic facies which has not before been observed in the Cordillera of Tierra del Fuego and which is very interesting on account of the great similarity with rock-types derived from strongly tectonized rocks occurring in other parts of the world.

It is above all interesting on account of the well developed, orientated (»gerichtet») crystallization (*cfr.* SANDER 50, SCHMIDT etc.) which here clearly proves that the recrystallization has occurred contemporaneously with the main folding and has finished at almost the same time as the latter. Later movements have also taken place, but they have not influenced the principal components, though on the other hand they have given rise to the origination of a later mineralization with sericite, epidote and chlorite, or in other words minerals characterizing the greenschist-facies. No distinct hiatus between the two movements and types of mineralization can be proved.

The relation between the greenstone-formation south of Fjordo Martinez and the metamorphic schists at Bahia Plüschow is still an open question. There is a striking difference in the general position of the layers at both places, and partly also in the style of folding. The first-named formations are altered and folded in a way which we generally find amongst the oldest pre-Cambrian rocks, and, broadly speaking, in rocks deformed and metamorphosed at a great depth. The mineral-paragenesis corresponds at least partly to the amphibolite facies. The latter show a more normal type of schistosity, found in the Central-Cordillera, and generally in mountain-regions characterized by nappe-tectonic of Central-Alpine style. The typical minerals originated at the metamorphosis are chlorite, epidote, albite, sericite (biotite) and quartz. Also minerals indicating contact-reactions, such as tourmaline, garnet and alkaline amphibole occur.

It is therefore not unthinkable that there really exists a disconformity between the two formations; the greenstone-formation would then represent an older part of the rock-ground, which through the orogenetic movements has been pushed up to a higher niveau. It might, however, also be interpreted, and as it seems with greater plausibility, as a deepseated root-zone of the overthrust folds or nappes of the Central-Cordillera. The quartzites, which are infolded with the supercrustal greenstones south of the fjord-end, prove that both formations in every instance must have been folded together, and the position of the folds makes it probable that the movements have taken place from the south towards the north.

Rock-types similar to those described from Bahia Plüschow and Bahia Sarmiento evidently compose the whole of the Cordillera Presidente Ibanez. They probably also extend westward to the Monte Sarmiento group, though we unfortunately have no personal observations in that direction. The rocks from the coast below (west of) Monte Sarmiento described by Lovisato (32) offer the only available data. They indicate that the mountain consists of schists of a similar type, both micaceous and greenstone-schists. Younger igneous rocks have not been found in this part of the Cordillera, and we are therefore entitled to draw the conclusion that the granitic core of the Darwin Cordillera is not visible in the westernmost part of the Main Island of Tierra del Fuego.

Fjordo De Agostini.

Fjordo De Agostini is of about the same length as Fjordo Martinez but is broader and more open. The direction is north-west—south-easterly. The

De Agostini fjord-valley differs morphologically from the valley of Fjordo Martinez in being a longitudinal valley, running almost parallel with the folding-axes of the Cordillera.

Also the coasts of Fjordo De Agostini are mountainous and mostly steep, but the topographical character is very different on the two sides of the bay. On the south coast the mountains descend very rapidly, often almost vertically, to the shore. The dark continuous mountain-wall is interrupted only by the numerous glaciers, which flow down to the sea through short, steep glacier-valleys. Ten big glaciers extend to the shore, and several of these calve, thus covering the surface of the water with icefloes.

The north coast is more indented, with several bays and rather lengthy valleys between the mountains. Broadly speaking, the coast strip is lower, and there is often a comparatively broad, low strip of land along the shore. Already from the sea the varying geological character is conspicuous. The stratification of the sediments of the cliffs is clearly visible, and the rocks seem to be comparatively less altered than the schists described in the foregoing pages.

The south-west end of the fjord is divided into two arms; both of these are narrow cliff-valleys between steep, glacier-polished mountain-walls. They end in big glaciers, reaching the water.

While the highland on the south coast has a fairly even crest, with few predominating summits, there are on the lower north side several isolated mountain complexes. The most remarkable of these are Monte Buckland, Monte Sella and Monte Aosta. The two last-named were named by De Agostini (1), who was the first to make any mappings in the fjord.[1]

On the north coast the glaciation is comparatively insignificant. There are only a few small hanging glaciers on the higher mountains; none of which reach lower than to 6—700 m above the shore.

T h e r o c k-g r o u n d on the south coast seems to be composed of gray micaceous schists of the same kind as around Fjordo Martinez. No landings were, however, made on that side. On the north side the rock-ground has a quite different character, and in the underlying layers consists of dark coloured metamorphic schists, higher up of comparatively well preserved sediments with clearly visible primary stratification. On this coast the author had an opportunity of investigating two localities: 1. The small harbour north of the

---

[1] The fjord was, however, known already before the visit of De Agostini in 1912. Attempts to found a farm at the north end, below Monte Buckland, had been made some years earlier.

inlet to the northerly end-arm of Fjordo Agostini, which here will be called Bahia Groth-Hansen, after Mr. G. Groth-Hansen of Magallanes. 2. Bahia Encanto, the bay below Monte Buckland.

Bahia Groth-Hansen **(20)**. The bay lies at the end of a deep valley of the Cordillera, which runs mainly in a westerly direction, for several km between high, glaciated mountains, rising to about 2000 m. Already a couple of km from the coast the valley is filled up by a lake, at least 3—4 km in length, which flows out to Bahia Groth-Hansen through a water-rich rivulet.

This tract is interesting *i.a.* because of the vegetation, which is astonishingly poor and different from the almost impenetrable rain-bush of the Cordillera. Here was found only very sparse vegetation of young *nothofagus*-bush, and none of the peatbogs so typical of the rain-region. The fjord has evidently so recently been released from the glacier, that there has been no time for the development of an older forest-vegetation. — Compare the interesting investigations of V. Auer, which are to be published in the near future.

The rock-ground of the valley and the surrounding hills consists of rather dense, but strongly folded and contorted black micaceous schists. It is folded in a more irregular manner than the mica- and greenstone-schists of Fjordo Martinez, and does not show the characteristic, more or less horizontal cleavage of the latter. The folds are here very complicated and partly vertical, with numerous differential folds and riffled shear-planes. The axis generally strikes 20—40°, dipping towards SE, often rather steeply.

In spite of its fine-grained structure, the rock proves to be recrystallized in a considerable degree. A typical constituent is pyrite in cubic crystals, evidently deriving from a primary sulphur-percentage of the sediment.

The schist described above occurs only on the lower part of the coast. In the valley there is an abundance of granitic boulders, showing that the high mountains behind at least in part consist of granite. Farther northwest, in the direction of the inlet of Fjordo De Agostini, the higher parts of the mountains are built up of reddish-brown, gently folded sediments. These rocks the author had an opportunity of examining more closely in the interesting locality of Monte Buckland (p. 62).

Microscopic description of the schists of Bahia Groth-Hansen.

Sp. 330. *Mica-schist*, Bahia Groth-Hansen, north coast of Fjordo De Agostini.

Megascopically the dark gray, rather fine-grained rock is folded into numerous, undulating miniature-folds. The principal mineral components are mica (muscovite and biotite) quartz and more sparingly albitic plagioclase. The structure is strongly parallel-schistose, with orientated crystallization of the small mica-flakes and also of the quartz. Along the shear-planes there is an abundance of black pigment, evidently carbon, which contributes

to the dark colour of the rock. Pyrite is an important accessory component. In addition, there is a number of small elongated tourmaline-crystals. They are dark brown in one direction, colourless in the other; the ends of the crystals are often bluish-gray.

The general impression of the rock is a comparatively strong recrystallization. Very little or nothing is left of the primary clastic structure. As later will be seen, there is a great difference between the sediments composing the upper part of Monte Buckland (p. 61) as well as the other mountains of the north coast of Fjordo De Agostini, and this schist on the shore.

Monte Buckland **(21).** Monte Buckland has already in early days attracted the attention of seafarers, both because of its height (1850 m), which makes the summit visible far out to the Strait of Magallanes, and because of its peculiar form.

The highest summit of the mountain is a rather narrow crest, striking about E-W, almost perpendicular to the axial-direction of the folding of the sediments.

EXPLANATION TO PLATE XI.

Fig. 1. Chlorite-schist with strong mylonite-structure The rock belongs to the metamorphic central-schists infolded in the quartz-porphyry-formation of Fjordo Finlandia. The dark mineral is mainly chlorite, the light-gray epidote, and the colourless quartz, and, to a less extent, albite. Colourless talc-strata along the shear-planes. Bahia Presidente Relander, Bahia Brookes. Magn. 14 ×. Nic. ‖.

Fig. 2. Deformed quartz-porphyry. Fjordo Finlandia, south of Seno Almirantazgo. Magn. 16 ×. Nic. +.

Fig. 3. Sericite-quartzite. Fjordo Finlandia. The mineral-components are mainly quartz, mica, chlorite and iron-oxide. The structure is conspicuously mylonitic. The rock belongs to the overthrust schists of the Central-Cordillera. Magn. 16 ×. Nic. ‖.

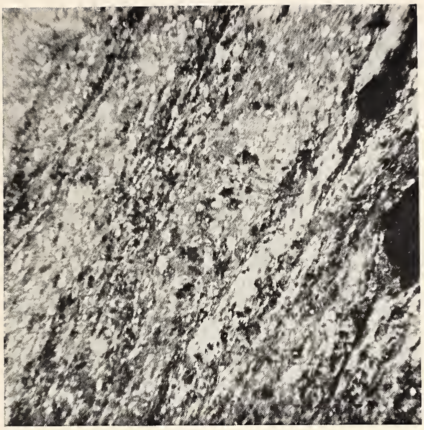
Fig. 4. Quartz-porphyry-tuffite with fragments of radiolarias. The rock is strongly sheared. Lower layers of the Monte Buckland series. Monte Buckland. Magn. 14 ×. Nic. ‖.

Fig. 5. Crystal-tuff with dense-packed fragments of quartz, plagioclase and microcline. Upper layers of the Monte Buckland series. Monte Buckland. Magn. 7 ×. Nic. +.

EXPLANATION TO PLATE XII.

Fig. 1. Basal-breccia or agglomerate composing the undermost layer of the Monte Buckland series. Monte Buckland.

Fig. 2. Dotted felsitic schist, belonging to the quartz- porphyry formation of Monte Buckland.



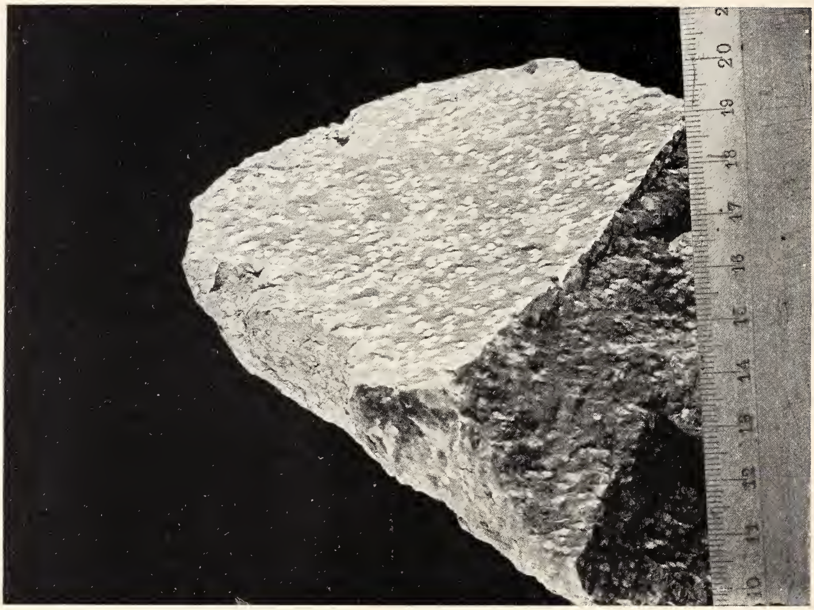
1

2

3

4

5



2

1

Fig. 15. The north wall of Monte Buckland. The low cliffs in the foreground consist of old micaceous schists, forming the base of the layers belonging to the Monte Buckland series visible in the cliffwall.
Photo V. Auer.

Fig. 16. Monte Sella with folded sediments of the Monte Buckland series.
Photo V. Auer.

Fig. 17. Quartz-porphyry tuffs interbedded with dark phtanitic schists. Monte Buckland, at about 500 m above the sea-level.
Photo E. H. K.

Fig. 18. Terrace-like plane at 800 m on Monte Buckland. The rock is a regularly jointed, dotted schist (*cfr.* Fig. 2, Pl. VI).
Photo E. H. K.

The south slope is interrupted by two offsets with terrace-like even plains (at about 800 and 1100 m), between which the slope is almost vertical (Fig. 15). Also Monte Sella close by is of a similar shape, and is geologically built of the same formations. Its highest summit is shaped almost like a needle, and attains abt. 1400 m above sealevel (Fig. 16).

From Puerto Encanto two valleys extend in a northerly direction on both sides of Monte Buckland; the more westerly of these traverses the whole of the peninsula as far as Bahia Cascada.

In order to get a geological cross-section of the mountain, the author climbed the north slope as far as the last crest under the summit. The s t r a t i g r a p h i c a l s e q u e n c e proved to be the following:

From the shore of Puerto Encanto up to about 250 m the rock-ground consists of the dark schist, described from Bahia Groth-Hansen. The average direction of the folding axes is ESE-WNW, dipping towards NW.

At 250 m, between the schists of the base and the overlying strata, there is a transitional zone of strongly mylonitized layers of varying aspect. Here the rock has been strongly rolled out and partly brecciated, owing to movements of the upper strata.

At 300 m one meets with a mylonitic sandstone-like rock, which farther up grades into an almost white dense schist. It is folded in small ripples, with an axial-direction of about 300°.

The following layer is a rather deformed conglomerate or breccia with pebbles up to 2—3 cm in size, composed chiefly of the basal-schist and a white quartzite-like rock. On the breccia rests a strongly mylonitic dark gray-black schist (mylonitic quartz-porphyry). The thickness of these formations is only about 30—40 m.

The following layer is again a coarse agglomeratic rock of the same composition as the first layer, though less altered. The pebbles are incompletely rounded, generally angular (Fig. 1, Pl. XII).

On the agglomerate lies a dark mylonite, which in a fine-grained, strongly lamellar-schistose ground-mass contains light phenocrysts of up to $^1/_2$ cm in diameter. Under the microscope the rock really turns out to be a strongly altered quartz-porphyry.

At 450 m there follows on the porphyry-mylonite again an agglomerate which has suffered but slightly by the deformation. The original form of the pebbles is well preserved. They still consist of both the contorted schist of the basal-layers and the overlying quartzite. The matrix is sandstone-like.

This complex of alternating quartz-porphyry-mylonites and agglomerates (conglomerates?) measuring about 200 m in thickness, is overlain by more

regularly stratified, less altered sediments, beginning from about 600 m above sealevel. These consist of thick banks of a seemingly weakly folded and altered yellowish-gray quartzite-like rock, which, however, proves to be a felsitic tuffite. It is rather fine-grained and particularly the undermost layers appear to be very pure. This horizon has a thickness of about 150 m. The strata slope gently northward (Fig. 17). They have evidently been comparatively resistant against the folding, which appears mainly in the grand style as big, simple folds, slightly overturned towards the north. — Higher up, the rock by and by becomes of finer grain and darker colour and is interstratified by thin layers of slaty schist. Contemporaneously the deformation becomes more conspicuous and is visible also in the hand-specimen (Fig. 19). The uppermost layers are very dense.

At 700 m begins a horizon (70—80 m) of light-gray, very dense schist, dotted with small (abt. 0.3 cm) round, white spots (Fig. 2, Pl. XII). The rock is

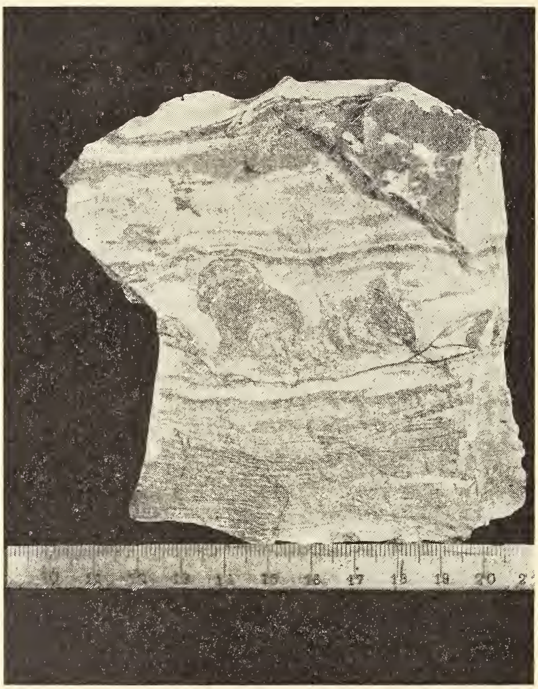


Fig. 19. Banded schist (quartz-porphyry tuffite) containing traces of radiolarias. Monte Buckland, about 700 m above sea-level.

generally jointed in a peculiar way, two vertical joint-systems crossing each other at almost right angles, causing a very regular disintegration of the schist (Fig. 18). The joint-directions are 230° and 140°. At 950 m, in the upper part of the dotted slates, a layer some 4 m thick, of a coarse, arcose-like clastic rock, evidently of tuffitic origin, with angular, well preserved grains was observed. The composition is remarkable because of a considerable percentage of microcline, indicating a close relation to the quartz-porphyries, which as a matter of fact is the only rock-type in this part of the Cordillera, with a content of potash-felspar of the type here in question (Fig. 5, Pl. XI).

The uppermost layers of Monte Buckland, from about 800 m upward, consist of black, carbon-rich, phyllitic slate, with a very perfect, plane-cleavage and brownish-red weathering surface. This rock was observed up to 1100 m above the sea and, as far as could be ascertained from that altitude, it occurs up to the highest summit of the mountains.

On the west slope of the top the vertical cliff-wall offers an excellent opportunity to study the style of folding in the phyllite. As a matter of fact, the strata are very much more moved than a superficial study would demonstrate; they form big folds, strongly drawn out in a horizontal direction, with almost horizontal folding planes. Also the axis is rather flat-lying and the sections therefore often give the impression of horizontal strata.

Regarded as a whole, Monte Buckland consists of three main elements: 1. The metamorphic basal schists composing the base of the other formations. 2. The mylonitic quartz-porphyry-agglomerate zone. 3. A less metamorphic sedimentary formation consisting of felsitic and phyllitic schists (*The Monte Buckland series*).

The microscopic investigations quoted below give some important facts which will contribute to the parallelization of the formations described with some other parts of the Cordillera.

Sp. 340. *Agglomerate.* Base of the Monte Buckland-formation (Fig. 1, Pl. XII and Fig. 4, Pl. XI). The rock consists of slightly rounded fragments of dark, contorted schist, felsitic schist and quartz in a strongly deformed, parallel-striated matrix of fine-grained quartz, sericite and a few big crystals of potash-felspar and quartz. The schist-fragments seem mainly to derive from the phyllitic sediments of the same formation, but partly also from the micaceous schist of the base. In both cases they have been strongly influenced after the formation of the agglomerate. The general character of the rock seems after all to correspond most closely to a tectonic breccia, although in many cases it also to a great extent remains a real conglomerate.

The other horizon in the basal-layer is of the following character.

Sp. 339. *Mylonitic quartz-porphyry tuff.* Underneath the undermost felsite-layers of Monte Buckland.

The rock consists of a strongly schistose, black ground-mass with small white phenocrysts, which under the microscope can be identified as felspar and quartz. Parallel to the movements the rock is traversed with numerous shear-planes along which black mica has crystallized. The new-crystallization is after all not conspicuous. In less sheared parts of the rock, there frequently appear fragments of a type resembling the dark fossil-bearing slates mentioned before. Also here traces of r a d i o l a r i a s are sometimes seen. Besides there are numerous felspar-fragments of both potash-felspar (partly altered into albite) and plagioclase, the latter being highly altered to epidote. The original crystal form is comparatively well preserved.

Sp. 342. *Felsitic tuffite.* (The yellowish-white layers of which the undermost part of the Monte Buckland formation consists). It is megascopically very like a fine-grained altered porphyry-rock. Microscopic examination, however, shows several features, which are more reminiscent of a tuffitic rock. The dense ground-mass of the rock is mainly a fine-grained matrix of quartz and plagioclase-grains, with solitary sharp-edged crystal fragments of plagioclase, potash-felspar and quartz. There can be no doubt that the quartzite-like, thick horizon of Monte Buckland is of tuffitic origin and closely related to the quartz-porphyries.

One is tempted to draw a parallel between this quartz-porphyry horizon with the tuffs and the well known porphyries of Seno Almirantazgo, as they in many respects have a similar petrographical character and evidently occupy the same geological position on the boundary between the high-metamorphic schists occurring in the Central-Cordillera and the less altered sediments in its marginal parts.

The next sediment-type in the sequence is the banded quartzite-like schist.

Sp. 334. *Banded felsitic tuffite,* the lower horizon of the upper tuffitic layers of Monte Buckland.

The rock consists of alternate light and dark bands about $^1/_2$ cm in thickness. The dark bands generally have the character of a fine-grained pelitic schist. They are usually highly fossil-bearing and can be regarded as r a d i o l a r i t e-b e a r i n g p h t a n i t i c s t r a t a. The light-coloured bands are mainly of tuffitic character, of the same kind as the underlying felsites.

An interesting rock is the peculiar *dotted schist* in the upper layers of the mountain (Sp. 345, 343, 347).

It is very fine-grained or dense and has a perfect cleavage. The megascopic aspect of the rock is shown by Fig. 2, Pl. XII. Under the microscope the rock generally appears to be of pelitic aspect, but also here we find abundant fragments, indicating relationship with the quartz-porphyries. It consists of a fine, dense, evidently for the most part siliceous (chalcedonic) ground-mass, with rather angular small quartz and felspar grains. Fine sericite-seams are scattered over the ground-mass except at the points where the white spots are situated. Here we instead generally find small epidote grains in abundance. Otherwise the structure and composition of the dots are the same as in the ground-mass.

The origin of these dots is difficult to explain. The content of epidote seems to indicate that they are more rich in lime than the surrounding parts of the schist, and they might be a kind of small concretions. Possibly fossils have contributed to their origin.

Closely related to the last-named rock-type and the quartz-porphyries is the medium-grained sandstone-like tuff mentioned already (p. 61) as occurring in the upper layers of the series.

Sp. 350. *Tuffite.* Monte Buckland 1000 m.

The sharp-edged, dense-packed (Microphotograph Fig. 5, Pl. XI) fragments composing this rock completely correspond to the constituents of the lower tuffitic layers of the Monte Buckland-formation. The big grains are not conspicuously influenced by tectonic movements, but the matrix is schistose and sheared. Besides the main components, among which particularly the big KNa-felspars are remarkable with their beautiful »Chess-board»-structure, there are some grains of a dark brown biaxial mineral with very strong absorption. This may possibly be an orthite.

Sp. 351. *Banded phyllite.* The crest of Monte Buckland.

The rock shows interstratified dark, carbon-rich layers and light-coloured tuffitic schist. The first-named have the same character as the radiolarites from Canal Beagle, etc. and also contain small fragments of an ophitic volcanic rock, corresponding to the types known from Isla Navarino, etc. Also remains of radiolarias are very abundant. There thus seems to be no doubt about the connection between the dark slate of this locality and that of the tracts around the eastern part of Canal Beagle, as well as the corresponding rocks from Seno Almirantazgo.

Microscopic examination of the rock-types of Monte Buckland shows that the quartz-porphyry-formation is of greater thickness than the field research rendered probable. The quartzitic schist must be interpreted as pyroclastic water-layered sediments, which here undoubtedly conformably underlie the black argillitic slates and radiolaritic schists of the Central-Cordillera. The agglomerates below also belong to the same formation and correspond in every respect to similar rock-types from the Azopardo region.

The recurrence of agglomerates and porphyries in this basal-zone evidently depends upon folding-movements which have increased the thickness of the horizon. Both the field observations and also the microscopic examinations indicate that strong movements have taken place along the contact of the Monte Buckland formation and the underlying metamorphic schists, although the stage of mylonitization does not provide very great overthrusts, but rather small movements under moderate stress.

It therefore is as yet difficult to decide if the contact in question is a primary one, if there is a disconformity between the old schist of the Central-Cordillera and the quartz-porphyry-formation, or if the contact is a tectonical one. Conditions in the locality described in the foregoing pages, however, rather point to the first-named suggestion.

Seno Keates — Punta Anxious.

Seno Keates, the inlet to Fjordo De Agostini and Fjordo Martinez, is bordered by high, steep mountains on the east and west sides. The south

coast, where the sound turns to the west, is lower, and in the north-westerly direction the channel here is continued by a broad valley, dividing the mountains of Peninsula Buckland into two separate groups.

The configuration of the mountains of the east coast is wild, with very steep slopes, and rugged crests with towerlike summits. The mountain-wall is cut by glacier-valleys of well developed cirque-form. Most of them are at present ice-free, only a couple of small hanging glaciers are seen near the crest of the ridge. The height is about 7—800 m.

The south coast is also high, but more indented, and has not such an abrupt slope. A rather deep bay called Bahia Queta is the most predominant feature on this part of the coast.

The rock-ground on the north coast consists, as far as could be judged from the ship, of dark schists with reddish weathering, similar to those in the upper part of Monte Buckland. The primary layering is clearly visible and seems generally to slope towards the north. The deformation is evidently not very strong.

On this coast no landing was made, but instead we had an opportunity to make a closer examination of the bedrock at the north end of Peninsula Buckland, at Punta Anxious. The locality visited was the innermost part of the narrow fjordlet Puerto Tristeza **(22)**. The fjord is about three km in length and is edged by high, almost vertical cliff-walls. It is continued by a forest-covered valley of the same shape, extending about 13 km from the fjord-end. A big glacier, evidently deriving from the extensive ice-fields which can be seen on the south side of Canal Gabriel, covers the end-wall of the uncommonly dreary valley. The Tristeza bay is open to the west winds, which are forced in between the steep cliffs, and it therefore is a dangerous harbour, with bad anchor-grounds.

The mountain-slopes consist of dark phyllitic schists, often beautifully banded, with layers of siliceous chert-like material, interbedded with carbon-rich slaty material. The rock is strongly folded. Big upright folds can be seen in the cliff-walls. The direction of the folding axis strikes almost parallel with the valley. It is nearly horizontal or slopes gently to the north. The deformation of the rocks is however not very conspicuous. Here we again meet the same type of dark slates as around the eastern parts of Canal Beagle and on the southern islands. As the microscopical investigation proves, they undoubtedly can be referred to the same stratigraphic series.

The rock on the place has the following petrographic character.

Sp. 303. *Cherty schist* (phtanite), Puerto Tristeza. The specimen is almost black-coloured, and very dense with a slight banding. Under the microscope it appears to con-

sist for the most part of layers with a dense, rather strongly rolled-out matrix containing abundant sericite, chalcedony, and sparsely scattered grains of well preserved plagioclase and quartz. Pyrite is present in abundance. These phtanitic layers are interstratified with carbon-rich slaty layers. — In the cherty parts there is an abundance of small round nodules, sometimes with crenelated edges, which can with certainty be identified as fossils (radiolarias). The nodules are generally filled with micaceous mineral and an iron-oxide pigment and chalcedony, sometimes also with calcite. They are exactly of the same kind as the micro-fossils which in the following will be described from the coasts of Canal Beagle (p. 109 and 149).

This rock can with good reason be called a radiolarite.

Probably the coast farther east consists of sediments of the same kind, though the shore-cliffs in the neighbourhood of Punta Anxious seem to be lighter in colour and from a distance bear more resemblance to the mica-schists of the Central-Cordillera. It is after all not unthinkable that the rocks on the shore could really consist of rocks of this kind, while the dark schists form the higher parts of the mountains, in the same way as along the north coast of Fjordo De Agostini.

On the south coast of Seno Keates one landing was made at Bahia Queta **(23)**; unfortunately this took place in very bad weather, and the observations are therefore very incomplete.

On the shore of a small bay on the west side, the rock was found to consist of a gray metamorphic schist of gneissic aspect. The degree of deformation is very strong and the original character therefore difficult to identify (Sp. 352—355).

Microscopic examination shows also similarities with a strongly altered dioritic rock, but on the other hand the mineralogical composition also could derive from a sandstone-like sediment (*cfr.* below). In every case it seems to be clear that it lies close to the boundary between the high-metamorphic central schists and the Monte Buckland-formation.

The pitch of the rock evidently corresponds nearly to the direction of the folding axis and trends from about north-east to south-west. The dip of the schistosity is gently northward, thus dipping underneath the slaty schists of the opposite coast.

Farther from the coast the mountain behind Bahia Queta evidently consists of micaceous schists, sloping gently in the same direction as the formation described above.

Schists of the same character also form the coast farther west. The layering of the schistosity shows that the folding-axis generally is almost horizontal, while the dip is northerly.

The microscopic investigation gives the following result:

Sp. 352—355. *Mylonitic schist*, Bahia Queta, Seno Keates.

Megascopically the rock is greenish-gray, fine- to medium-grained, generally with well developed schistosity.

The mineral components are mainly the following: felspar, quartz, epidote, chlorite, apatite, titanite, ilmenite and rutile (?). The structure shows a strong mylonitization. The quartz-grains are completely crushed up and undulose. The felspar-grains are less affected by mechanic deformation, but strongly saussuritized. Only in few cases is the mineral clear enough to allow an optical determination. The composition is albitic; also potash-felspar possibly occurring in small quantities. The quartz and the felspar occupy at least 70 % of the rock. Chlorite is the dominating dark component. Also epidote is abundant, generally growing together with the former. Titanite occurs in the form of coronas around the ore-mineral of the rock. A dark short-prismatic uniaxial (+) mineral with strong pleochroism, was interpreted as rutile. The absorption is almost complete in the c-direction, the cross-direction is dark brown.

With regard to composition the schists seem to correspond to a diorite or granodiorite which has been metamorphosed in connection with strong movements and mechanical stress.

Bahia Cascada — Bahia Fitton.

On the south coast of Bahia Cascada — the continuation of Canal Gabriel — the shore-cliffs have the same aspect, seen from the ship, as on the shores of Canal Gabriel. They are probably dark slaty schists of the same kind as those described from Bahia Tristeza at the other end of the channel.

The two-armed fjordlet Bahia Fitton **(24)**, in whose west arm two glaciers end in the sea, is surrounded by high, snowcovered mountains. Around the inner part of the south arm the mountains are lower, and here the bay ends in a low broad valley.

The high mountains on the south side belong to the same complex as Monte Buckland, Monte Sella etc. Right at the inlet of Bahia Fitton, there rises on the south shore an imposing *massif* with a rugged crest, reaching about 1500 m above the sea-level (Fig. 20). The steep north slope gives a splendid profile through the higher part of it and clearly shows the tectonic style.

The rock is a schist with brownish-red weathering, evidently the same as that at the top of Monte Buckland. Also the style of folding is in some degree similar. The schist-layers are folded in very drawn-out, overthrust folds. Extensive horizontal movements evidently occurred here, and in connection with these the slates have been strongly deformed. There is no doubt

that this rock-complex has been thrust over the less folded schists around Canal Gabriel and at Isla Dawson.

On the north side of the inlet sediments of grayish colour occur. They are softly folded, and seem to belong to the Cretaceous sandstones. The layers dip genera ly to the north. It is probably the same rock-type which earlier has been described (p. 34) as occurring at the easternmost end of Isla Dawson (Cabo Expectation).

Fig. 20. Overthrust argillitic schists belonging to the Monte Buckland-series, forming drawn-out, lying folds. Monte Biella seen from Bahia Fitton. Photo V. Auer.

A little west of the inlet to Bahia Fitton there is a mountain with a rounded crest, called Cerro Curioso on the charts. It appears to consist of less contorted sediments of the same type as on Isla Dawson, north of Canal Gabriel.

North of the inlet to Bahia Fitton there rises another mountain called Monte Sherrade; a small *massif* about 700—800 m in height and evidently consisting of Cretaceous »Flüsch»-sandstone. The layering on the shore is clearly visible from the sea, and dips 25° to 30° to the south.

3. Seno Almirantazgo and Bahia Brookes.

Seno Almirantazgo (Admiralty Sound).

Seno Almirantazgo is about 75 km in length, with a breadth of more than 10 km, and is the biggest of the fjords of Tierra del Fuego. From a geological and also morphological point of view it is particularly important, being the boundary between the Central-Cordillera and the Marginal-Cordillera.

The different geological structure of the two coasts is apparent already from the topographical forms. Whereas the mountains of the north coast, except in the innermost parts, have rather rounded forms, those on the south side are typically Alpine in character, with rugged crests and high, peaked summits, generally covered with ice.

The fjord also forms the climatic boundary (Skottsberg (52), De Agostini) the tracts on the north side belonging to the transitional zone between the rainy High-Cordillera and the dry pampa, where the precipitation is high enough to permit a rich and high forest vegetation, but not so high as to grow the typical dense bush-like rain-wood.

The north coast of the fjord is rather straight and the broad pampalike valleys nowhere form harbours and bays of importance. Only near the east end the bay at Estancia Marta offers a safe anchorage.

The south coast is very indented and cut by several big bays and fjordlets, this feature evidently being due to the fact that the base of the cordillera-valleys on this side lies below the sea-level, whereas on the opposite coast it is higher. The biggest of these fjordlets are Fjordo Parry (the easternmost), Bahia Ainsworth and Bahia Brookes.

Between the end of Seno Almirantazgo and the inlet of Fjordo Parry the coast is very steep (Fig. 21), rising abruptly from the shore, to about 300 m. At about that height there is generally a terrace-like offset, which sometimes is up to a couple of km broad. Above the plateau the High-Cordillera topography begins with naked rugged cliffs and snowy peaks.

The two-armed Fjordo Parry extends southward right to the foot of the High-Cordillera. The main arm is fjord-like and surrounded by high, steep mountains. It has the character of a cross-valley. The westerly arm, called Laguna Blanca, is open and broad and ends in a valley extending some km inward from the coast.

Bahia Ainsworth is the outermost end of a great valley which is but partly covered by the sea; the upper part of the valley ascends rather rapidly to the High-Cordillera. It is covered by the big Marinelli-

glacier, the biggest of the numerous ice-streams of Tierra del Fuego. The morphological character of Bahia Ainsworth seems to be similar to that of Fjordo Parry.

Between the inlets of the two fjords named above the coast is comparatively low, rising only a couple of hundred metres. The crests are rounded by the ancient glaciation. West of Bahia Ainsworth there is again a rather high mountain-complex called Monte Seymour. The difference in topography here evidently is due to the difference of the rock-ground (*cfr.* the map).

On existing maps Bahia Brookes, the westernmost of the branch-fjords of Seno Almirantazgo, is marked as a rather short bay, with a length of about 6-7 km. A survey made by the Finnish expedition 1929 showed, however, that this bay in reality is the biggest of all the three fjords. It is therefore described in a separate chapter, especially as it was the only one of the fjords named above which was the subject of investigation on our journey.

In the easterly direction Seno Almirantazgo is continued by the great Azopardo valley and the Lago Fagnano-depression, which as far as we know in every respect is morphologically connected with the first-named fjord (NORDENSKJÖLD, QUENSEL).

The geology of Seno Almirantazgo has been dealt with earlier by NORDENSKJÖLD, QUENSEL and BONARELLI (41, 47, 11). These authors have especially described the porphyry-formation in the district of the Azopardo-valley and around the west end of Lago Fagnano. The rocks in this part of the country are therefore comparatively well known from the petrological point of view. The sedimentary rocks on the coasts of Seno Almirantazgo are, however, not described in the papers of these authors, and a few observations made by the present author may therefore be quoted.

The north coast of the fjords consists of sediments belonging to the Cretaceous »Flüsch»-layers, at least in the western part of the fjord. In the foregoing (p. 35) there has been described the sandstones of Puerto Arthuro which partly contain inclusions of schists belonging to the Central-Cordillera series. The coarse sandstones seem to occur along the shore up to about 5—6 km east of Puerto Elenita. Westward the cliffs consist of dark slate with perfect cleavage.

Puerto Elenita **(25)**. Here occurs a black dense slate which in some degree resembles the old schists on the opposite coast of the fjord (Sp. 392). Under the microscope the rock appears to be considerably mylonitized. Of the components only scattered grains of crushed felspar and quartz can be identified. Around these grains bend shear-plains rich in carbonaceous pigment. On the moving planes there also are small quantities of sericitic

minerals. The rock is poor in carbonate and microfossils are quite absent. The last-named fact makes it rather probable that the rocks belong to the Cretaceous sediments, forming the undermost part thereof.

The south coast consists entirely of more or less crystalline rocks. The most important of these are the quartz-porphyries, which Quensel has been able to follow along the whole of the eastern front of the Patagonian Cordillera.

Also on Tierra del Fuego these porphyries evidently are of greater extent than earlier was known, and also here they generally are found along the front of the mountain-chain, though they, as later will be seen, have also been observed as infolded. Bonarelli has on his geological map (11) marked a continuous band of porphyries along the whole of the Cordillera from Strait la Maire along Lago Fagnano and Seno Almirantazgo and further Peninsula Buckland to Peninsula Brunswick on the north of the Strait of Magallanes. Most parts of the area in question have, however, never been visited, at least not by any geologist and the extension of these rocks is therefore for the present only hypothetical, though many facts support such an assumption.

In the Azopardo valley, however, and along the south coast of Seno Almirantazgo, the rock has really been proved to exist, following the whole of the southern boundary of the depression.

The formation seems to reach its greatest breadth just in the tract of Rio Azopardy and gradually narrows farther to the west. Bonarelli believes that both Seno Almirantazgo and Lago Fagnano are underlain by porphyries, and that the whole fjord- and lake-depression is due to the less resistant porphyric rocks having been excavated (11). To the present author this hypothesis seems to be rather improbable. In every case we know that the layers of porphyries found farther west are very thin and that the general strike of the formation does not indicate that the rocks continue along the bottom of Seno Almirantazgo. Furthermore, the islands Tres Magotes in the middle of the fjord at the east-end do not consist of porphyries, but of slaty schists.

Besides at the end of the fjord, the quartz-porphyries compose the south coast as far as Bahia Ainsworth. The present author had an opportunity to prove the existence of the formation on the north shore of the peninsula formed by the innermost part of Seno Almirantazgo and Fjordo Parry, and at Puerto Haycock between the last-named fjord and Bahia Ainsworth.

T h e p o r p h y r i e s o f S e n o A l m i r a n t a z g o are light to dark greenish-grayish rocks, often felsitic, but generally with dense ground-mass and phenocrysts of felspar and quartz. An almost constant percentage of pyrite gives the rock a yellowish to reddish weathering surface.

Besides the porphyric rocks, the complex also contains an abundance of tuffitic layers, clearly indicating that the formation is of supercrustal origin. Of great interest is the occurrence of normal, pelitic, generally banded sedimentary layers between effusive masses of porphyry and the porphyry tuffs. They will be treated in another connection. Also porphyries with banded structure are sometimes found.

The mineralogical composition is, taken as a whole, characterized by rather varying proportions between the content of plagioclase and potash-felspar; on an average the first-named seem to be slightly more common, as is the case in almost all the igneous rocks of the Cordillera. As the analyses given by QUENSEL (47) show, however, there are also found pure potassic rocks. All the varieties investigated by the present author from the more westerly parts of the Almirantazgo region are plagioclase-bearing.

The outer aspect of the rocks varies greatly, not only owing to the different lithological character, but also because of the very varying degree of tectonic alteration. From the SE-parts of Monte Hope, QUENSEL (47) describes porphyries almost without any trace of alteration, and rocks of the same kind occur at the outlet of Rio Azopardo from Lago Fagnano. The rock is there a black, sometimes fluidal (?) felsite-porphyry with porcelain-like white phenocrysts of potash-felspar and black quartz in abundance. The quartz-grains are always strongly corroded.

The author found porphyry of the same kind as loose boulders at Puerto Elenita on the north coast of Seno Almirantazgo, and they have been found also farther north in the tracts of Lago Deseado.

The most part of the quartz-porphyries of Tierra del Fuego have, however, in a high degree suffered through tectonic alteration and have in connection herewith also undergone chemical metamorphosis. In several localities they are strongly schistose and can only with difficulty be identified. At Seno Almirantazgo the primary character is, after all, never completely destroyed. Many of the structures which have earlier been interpreted as primary fluidal-structures seem, however, rather to be deformation-structures. This is evidently the case with the structure on the photograph published by NORDENSKJÖLD (41, Table XVI, Fig. 2). The chemical alteration in connection with the deformation has been discussed by QUENSEL. It is mainly a zoisitization of the ground-mass in connection with an intense sericitization. The felspar phenocrysts are also completely altered and no longer to be distinguished from the ground-mass.

As a complement to the descriptions of the porphyries of the Azopardo valley by QUENSEL and NORDENSKJÖLD some data will be given below relating

to a locality not hitherto investigated and lying farther west of the localities dealt with by the first-named investigators.

The author made some observations on the porphyries in the neighbourhood of La Paciencia **(26)** on the S coast of Seno Almirantazgo opposite the islet Los Tres Magotes.

On the shore east of La Paciencia the cliffs consist of a strongly sheared clastic rock, composed of big, elongated boulders embedded in a matrix, which resembles a deformed sandstone. The rock is strongly schistose and mylonitic. The major part of the boulders consists of dense, aphanitic porphyry, together with thinly scattered pebbles of black schist. The whole formation must be interpreted as a tuff-conglomerate or breccia. The same kind of

Fig. 21. Strongly jointed quartz-porphyry-cliffs at La Paciencia near the E end of Seno Almirantazgo. Looking west. Photo E. H. K.

agglomerates have also been observed in the Azopardo district. The formation is at La Paciencia interbedded with thin layers of black phyllite-like rocks or phtanites.

The strike is 60°, the dip 25° S.

Higher up the mountain-slope a quartz-porphyry is found, and the same rocks also form the shore-cliffs at La Paciencia (westward). The surface of the rocks is yellowish, owing to strong weathering, depending on a comparatively high percentage of pyrite. This is also the reason why attempts at mining have been made here (Fig. 21).

Owing to tectonic stress the whole complex is crossed by numerous open joints, sometimes causing a brecciation of the porphyries. The predominating joint-directions are the following: E-W, dip 70—80 S and 340°, dip 90. The

joints are partly filled with quartz, partly with calcite. The weathering-products are generally rich in carbonate, and the gravel on the shore below the cliffs is in some places completely consolidated to a carbonaceous conglomerate.

The brecciated character of the quartz-porphyries is noticeable along the whole south coast of Seno Almirantazgo and is one of the most interesting and important features of the formation. The brecciation is obviously much younger than the deformation of the agglomeratic schists and phyllites at this place, and has nothing to do with the old folding which caused that deformation, *i.e.* the movement which has given rise to the schistosity of the Central-Cordillera schists. It belongs to comparatively late movements, which have acted near to the earth-surface, otherwise the incompletely consolidated character of the breccia could not be understood. As will be seen later, there must have been such movements in connection with the folding of the younger, Cretaceous sediments of the Marginal-Cordillera (p. 216).

On the island opposite La Paciencia there occurs a banded slate, resembling the phyllites of Monte Buckland (Fig. 1, Pl. XXVI). The microscopical examination showed also similar features in both rock-types, and proved further that we also here have to do with a radiolaritic schist.

Sp. 18. *Banded schist,* Los Tres Magotes, Seno Almirantazgo.

The rock consists of dark phtanitic layers about one cm in thickness, alternating with light-coloured layers rich in tuff-material. The first-named consist mainly of a cryptocrystalline dull mass of chalcedony in which there are abundant fossiliferous nodules, evidently slightly deformed radiolarias of the same type as those described from *e.g.* Monte Buckland. A fine pigment of carbon, and also iron-oxide, gives the dark colour of the rock.

The light-coloured, tuffitic layers are also for the most part cryptocrystalline, but contain also crystal-fragments of felspar and quartz in abundance.

This rock can with certainty be referred to the same formation as the sediments of Monte Buckland. It here evidently underlies the quartz-porphyry-formation. It is, however, probable that this sequence is not normal, because the porphyries seem to be overthrust, and the underlying layers are therefore, in contrast to the porphyries above, highly tectonized and schistose. Here at Seno Almirantazgo we evidently originally had the same stratigraphical sequence as has been described at Monte Buckland, *i.e.* with the quartz-porphyries lying under the slaty schist. At Seno Almirantazgo the sequence has been turned upside down. The observations are, however, still too scarce to permit any more detailed interpretation of the tectonic conditions (see the stereogram

Fig. 59, p. 210), which may be still more complicated than the preliminary surveying indicates.

The fact that less altered quartz-porphyries have been found farther north seems to indicate that the porphyries have been tectonized on the outer edge of the overthrusting movements of the Central-Cordillera.

The petrographical character of the porphyries from the localities described above is in general the same as in the rocks described from Azopardo, with the exception of the slightly higher degree of tectonic alteration, and the higher content of plagioclase (with 38—28 % An).

Bahia Brookes — Fjordo Finlandia.

The easternmost of the three big fjords, on the south coast of Seno Almirantazgo, looks very modest when seen from the inlet, because of the comparatively insignificent height of the mountains around its outer parts. It has therefore in less degree than the two branches described earlier been the subject of surveying.

Fig. 22. The end of the E Arm of Fjordo Finlandia with the Finlandia glacier. Photo E. Hyyppä.

On the existing sea-charts the form differs very much, but the length given is generally only about 6—7 km. On the most recently published map of Tierra del Fuego, the world map of THE AMERICAN GEOGRAPHICAL SOCIETY, scale 1 : 1 000 000, the same as that on the American sea-chart, has been maintained for the bay. The only improvement is the addition of a glacier at the end, probably in consequense of data obtained by the CHILEAN COAST SURVEY (*Annuario Hydrographico* 1907).

In March 1929 the Finnish expedition made a reconnaissance to the innermost part of the bay. It was then seen that the fjord had a length far greater than shown on the earlier maps, cutting for more than 30 km right into the most central parts of the Cordillera. It ends in a two-branched fjordlet, which is hidden from Seno Almirantazgo by high mountains. As a memento of our expedition this fjordlet was named Fjordo Finlandia.

The outward part of Bahia Brookes is an open bay, sheltered on the outside by the small island Hight. The main direction is 160°, the width is about 4 km. This part is visible from Canal Whiteside and ends toward a high mountain with a snow-covered crest. On the NW side of the mountain there is a glacier tongue, which does not reach the shore. This glacier has evidently been marked on the newest map, though the distance from the inlet of the fjord is estimated at too short a distance.

The western coast of Bahia Brookes is fairly straight, there being only a few small, open bays. On this side two rather big valleys reach the shore.

The west coast is very indented. At the inlet there is a long, low point, called Punta Esperanza on the chart. Some km farther south a bay about 6 km long is seen. It is continued in WSW-erly direction by a broad, low valley separating the Monte Sherrard complex from the High-Cordillera. The valley evidently reaches right to the eastern arm of Bahia Fitton. On the south side of the mountain-slope there are some small hanging glaciers, on the opposite side the crests are bare. About 2 km from the end of the bay a small lake was found, its outflow being directed westward. The watershed is consequently very near Bahia Brookes and the isthmus can scarcely be more than 5—6 km.

The Finnish expedition named the bay Bahia Kairamo.

Farther southward the mountains gradually become higher and the crests are ice-covered.

Some 20 km from the inlet there opens to the view a broad bay of considerable size. At its end a big two-branched glacier reaches the coast. On the south side there are a couple of small islands. Near the shore, the north coast is partly lower and has some small valleys with wood-vegetation and

Fig. 23. General view of Fjordo Finlandia (left) and Bahia Brookes (right), seen from Cerro Nylandia. The picture comprises an angle of 120°. Photo E. H. K.

swamps, but in general snow-covered mountains rise rapidly to a considerable height around the bay, and in the innermost end large ice-fields open to the eye (Fig. 28). — The bay is in the following description called B a h i a P r e s i d e n t e R e l a n d e r, in honour of the former President of the Finnish Republic.

Southward the fjord narrows. Both shores are very steep and almost straight, up to about 25 km from the inlet. Here it abruptly turns to the west and continues in a SW-erly direction, as a 2—3 km broad arm surrounded by high ice-covered mountains, from which several glacier-tongues reach down to the shore (Figs. 22, 23). This arm is about 8 km long. At its end a great glacier-wall runs down to the sea and throws its ice-masses into the bay, the water of which is covered with ice. The inner part of the fjord-arm is blocked up by a moraine-wall, which reaches almost to the surface of the water.

Another arm stretches in a SE-erly direction about 8 km (Figs. 25, 26). It also ends in a tremendous glacier, flowing down from the high mountains behind the fjord, which reach to at least 2000 m above the sea-level. — The end-glacier of the east arm was called V e n t i s q u e r o R u n e b e r g (Fig. 27) after the national poet of Finland, while that of the west arm was called V e n t i s q u e r o F i n l a n d i a (Fig. 22). The name Fjordo Finlandia will in the following be used for the continuation of Bahia Brookes, from the point where it changes its direction.

The sketch-map annexed (Fig. 24, p. 78) is made after a compass-survey by the author. It gives only the main features of the fjord, and makes no pretence of any great accuracy, but it gives at any rate a more correct idea of the shape of Bahia Brookes than do the earlier maps.

More detailed mapping and surveying of the district was unfortunately rendered impossible through illness attacking the captain of the expedition's ship, which made it necessary to reach inhabited districts as soon as possible, and compelled departure before the investigation was concluded.

The vegetation of Fjordo Finlandia showed the same very young character as that of Fjordo De Agostini, showing that the land had only comparatively lately been released from the ice.

Geology.

Bahia Brookes — Fjordo Finlandia is important from a geological point of view because it gives a good cross-profile through the north front of the High-Cordillera, as far as the central part.

On the east side of the inlet rises Monte Seymour, consisting of steeply folded sediments, of a reddish-brown colour, probably of the same kind as at Puerto Tristeza. The layers in general dip to the north, and do not seem to be altered to any noteworthy extent.

The same kind of sediments also occur on Isla Hight.

On the opposite side of the inlet the shore-cliffs are grayish-green and evidently consist of Cretaceous sandstone. In the mountains behind there are flat-lying sediments in thick banks, slightly dipping to the west.

At Bahia Kairamo **(27)** the rock-ground at the end of the bay is a rather coarse grayish-green sandstone or graywacke, interbedded with layers of banded black slate. The bands are generally only some few cm thick. The strike is 300°, the dip 30° S. The rocks may with fairly great certainty be determined as belonging to the Cretaceous »Flüsch»-sediments of the Marginal-Cordillera.

Microscopic examination gives the following result:

Sp. 389. *Psammitic graywacke.* Bahia Kairamo, Bahia Brookes.

The rock is coarse-clastic, consisting of sharp-edged mineral grains of very varying composition (size of the grains $^1/_2$-1 mm). The dark components form more than 50 % of the rock, and give it its greenish-gray colour.

Under the microscope there appear great quantities of fragments of a diabasic rock, sometimes vitreous. Of the colourless mineral-grains the most abundant are quartz and plagioclase in almost equal quantities. The composition of the latter is generally about 30 % An. Grains of potash-felspar occur more sparsely. Among the dark components augite is very abundant. In addition there are green hornblende and a chloritic mineral, the last-named as an alteration product of biotite or as rounded grains, probably glauconite. The fine matrix of the rock seems for the most part to be composed of epidote, sericite and chlorite.

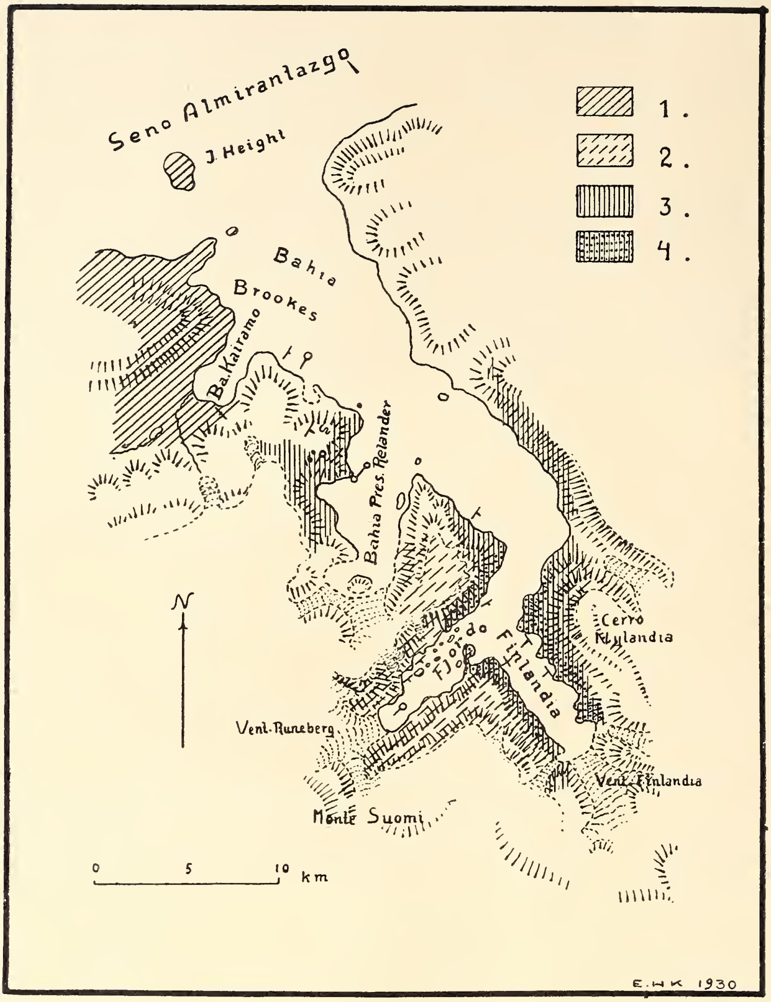


Fig. 24. Bahia Brookes and Fjordo Finlandia. Sketch-map according to compass-survey by the author.

1. Cretaceous »Flüsch». 2. Overthrust centralschists. 3. Metamorphic schists of the Monte Buckland series. 4. Quartz-porphyry-schists and tuffs.

Sp. 390. The dark slate appears under the microscope as a pelitic sandstone of almost the same character, but very fine-grained and with abundance of carbonaceous material. It also contains small quantities of pyrite. There are no traces of fossils in the rock.

South of Bahia Kairamo follows a zone where the sediments are folded in an extremely high degree. Nearer the bay described above, there are in

Fig. 25. The West Arm of Fjordo Finlandia, looking from Sierra Nylandia.
Photo. E. H. K.

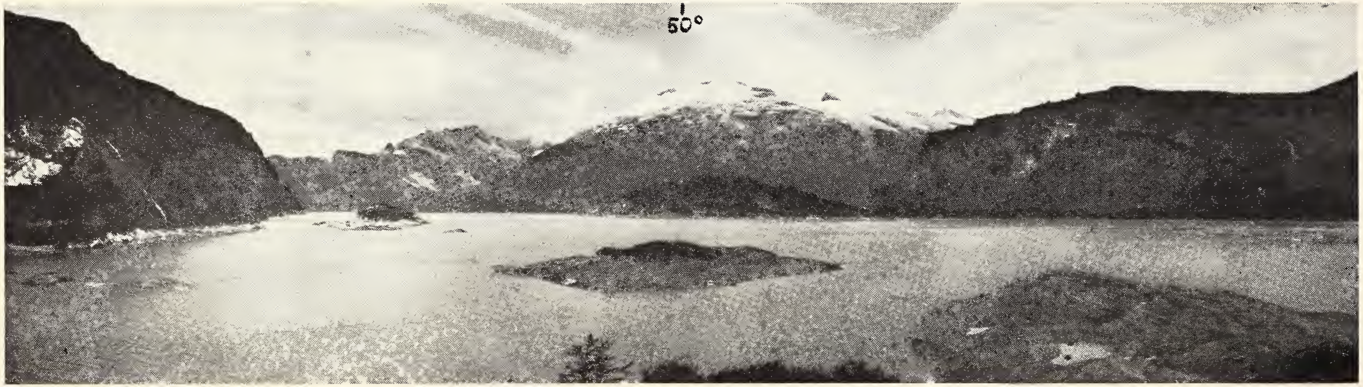


Fig. 26. The West Arm of Fjordo Finlandia. Looking towards the inlet.
Photo. E. H. K.

Fig. 27. The Runeberg glacier at the end of the West Arm of Fjordo Finlandia. The cliff-walls consist of strongly deformed schists of the Central-Cordillera. The south-westerly axial-dip is (towards the glacier) well visible in the wall on the left hand.
Photo. E. H. K.

Fig. 28. The mountains of the N shore of Bahia Presidente Relander.
Photo. E. H. K.

Fig. 29. Quartz-porphyry cliffs with strong flat-laying schistosity. S-shore of the E Arm of Fjordo Finlandia.
Photo. V. Auer. Looking N E.

Fig. 30. The end of the W Arm of Fjordo Finlandia. The cliff-walls in the background are overthrust quartzitic schists of the Central Cordillera. In the foreground quartz-porphyry schists, overriden by the first-named.
Photo. V. Auer.

the shore-cliffs brownish sediments of the same type as at Monte Seymour on the opposite shore. The layers are generally almost vertically folded and often show slopes and overthrustings. Farther south, the strata higher up the mountains consist of strongly folded, light-coloured sediments. Above them there are again dark-coloured rocks, in which the folding is less conspicuous. The light-coloured sediments, which are also visible on the west side of the fjord, are probably quartz-porphyroidic layers of the same character as the undermost strata of Monte Buckland. They are here at least in some degree overthrust over the Cretaceous sediments, on the front of the Cordillera.

Bahia Presidente Relander **(28)**. A landing was made at the north-east point. The rock ground here has a quite different character. The dominating rock-types form thick series of quartz-porphyries and porphyry tuffs. They are generally very strongly deformed and altered into sericitic schists. The tuffitic rocks seem to be more abundant than the quartz-porphyries.

Besides there are agglomeratic rocks, completely resembling such described from La Paciencia in the east end of Seno Almirantazgo (p. 72) and the breccia under Monte Buckland. There is therefore no doubt that we have the same horizon at all these localities, and the porphyry- and conglomerate-formation consequently is a very extensive zone in the front part of the Central-Cordillera, as already QUENSEL and later BONARELLI have pointed out.

The porphyry and agglomerate beds at Bahia Pres. Relander differ from the corresponding horizon of Monte Buckland in having an almost vertical position, and have evidently been infolded between the metamorphic schists of the Central-Cordillera and the sediment of the Marginal-Cordillera. The strike is 250°. South of the porphyry formation there occur on the NE-point of the bay highly sheared chloritic schists with flat-lying schistosity, gently sloping to the S. They are cut by greenstone dikes with less conspicuous deformation-structure.

The chlorite schist (Sp. 386) consists of fine strata of chlorite and epidote, alternating with calcite and quartz-layers. The parallel-structure, connected with a strongly developed shear, indicates a complete recrystallization of the rock, which has destroyed every sign of primary structures.

The greenstone dike (Sp. 387) (Microphotograph Fig. 1, Pl. XI) resembles highly the ophiolitic greenstones from the Central-Cordillera. It is a rather structureless aggregate of epidote, chlorite, calcite and albitic plagioclase (9—10 % An). The plagioclase-grains are allotriomorphic and embedded between the chlorite and epidote, and contain abundant inclusions of the latter mineral.

Evidently the first-named schist is to be referred to the old basal-formations of the Central-Cordillera. It possibly represents supercrustal greenstones infolded and metamorphosed in connection with the orogenic movements, while the dike corresponds to similar dikes found cutting the schists in several places.

The petrological character of the quartz-porphyries completely corresponds to that of similar rocks at Seno Almirantazgo, though the deformation generally is more conspicuous, and the tuffitic rocks are more abundant than pure porphyries.

From Bahia Pres. Relander southward the mountains are composed of strongly altered and sheared schists of Central-Cordillera-type, dipping towards the south, in places rather steeply. At the inlet of Fjordo Finlandia **(29)** at the foot of the high mountain which is visible right out to Seno Almirantazgo (Cerro Nylandia, Figs. 25, 26), the closer investigation of the rock-ground gave a rather astonishing result.

It consists on the shore of a dark, brownish-gray, deformed schist, interbedded with thin greenish-black layers. On the shear planes there are 1—2 cm long radiated crystals of dark-green tremolite.

Along the E-arm of Fjordo Finlandia there occur beautiful pure white, quartzite-like schists, disintegrating in regular about 2 cm thick flakes (Fig. 29). The axial-direction is SW-erly and the dip is in the same direction. These layers consequently are situated in a higher horizon than the foregoing ones. Microscopic examination has proved that these white schists as a matter of fact are no sediments but igneous and pyroclastic rocks. T h e y f o r m q u a r t z-p o r p h y r i e s a n d t u f f s which in spite of the strong deformation still show typical primary structures, such as well preserved phenocrysts of plagioclase, microcline and quartz in a fine-grained ground-mass of felspar and quartz. Dark components are almost entirely lacking. In several of the porphyries no potash-felspar is found. The plagioclase has the composition 22—25 %. An. in the main zone, 32 % in the kernel of the crystals, 19 % in the outermost parts. Occasionally the rock grades into sericite-schists. (Sp. 375, 379). In addition there are layers of a rather dark-coloured, fine-grained, normal quartz-porphyry (Sp. 374, Microphotograph, Fig. 2, Pl. XI).

Higher up the mountain-slope there occur quartz-rich schists and typical porphyries of the same aspect, at least up to 600 m above the sea-level.

There is in several places a considerable enrichment of sulphides in the rocks, which greatly resembles similar occurrences on the south-coast of Tierra del Fuego (Lapataia, Jendegaia p. 86). The ore-minerals are galenite, sphalerite and calcopyrite.

This formation seems, in spite of the very strong alteration, to be of the same kind as the quartz-porphyries along the northern border of the Central-Cordillera, particularly the quartzite-like schists have undoubtedly the same character as the pyroclastic sediments of the Monte-Buckland formation. Here they merely have another position and are more tectonized. The occurrence of dark, comparatively slightly tectonized, argillaceous sediments below and more metamorphic schists above, indicates the possibility of an inversion of the stratigraphic sequence due to tectonic conditions.

Should the quartz-porphyry-formations around Fjordo Finlandia really belong to the same group as the Azopardo-rocks, this proves that these porphyries also occur in the inner parts of the Central-Cordillera in strongly metamorphic condition, and that it therefore is hardly possible

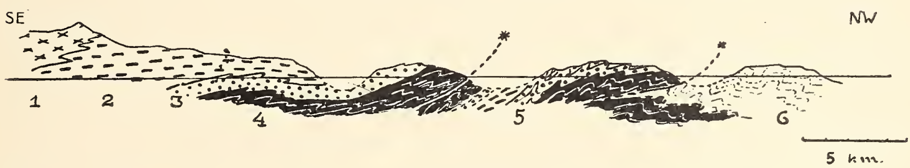


Fig. 31. The probable tectonic of the front-section of the Central-Cordillera at Fjordo Finlandia and Bahia Brookes.

1. Cordillera-granite, 2. Overthrust centralschists, 3. Quartzporphyry, 4. Schists of the Monte Buckland-series, 5. The quartz-porphyries of Bahia Relander, 6 Cretaceous »Flüsch»-sandstones. Drawn by E. H. K.

to separate the old central schists (older than the Monte Buckland-formation) and the fossil-bearing slates of the Monte Buckland series in these parts of the mountain-range.

In the west arm the rock-ground is composed of micaceous schists, mainly sericite-quartzite-schist. They are generally strongly linear, with the pitch dipping 15—30 SW. (Sp. 230—240, Microphotograph Fig. 3, Pl. XI). Southward the general schistosity becomes very flat. The schists here lie still higher in the sequence and probably belong to the older central-schists lying above the younger porphyries. (Overthrust, *cfr.* Fig. 30).

On the shore of the east arm was found an abundance of big angular boulders of gray, medium-grained granite, with slight signs of tectonization. They evidently derive from the high summits behind, and indicate that the granite-core of the Cordillera extends from the Darwin-Cordillera to these tracts. —

This is also proved by the fact that the boulders which the Marinelli-glacier brings down to Bahia Ainsworth for the most part consist of coarse-grained gray granite (According to Captain Hanson of Magallanes.). The petrographical character of this granite will be dealt with later on in another connection (p. 195).

4. Observations in the Central-Cordillera along the south coast of Tierra del Fuego.

The North-West Arm of Canal Beagle.

Whereas, with the exception of Seno Almirantazgo, the parts of the Central Cordillera described in the foregoing chapters have never before been the subject of geological research, several points on the south coast are comparatively well known. The available data from this region are derived mainly from the investigations of the French Romanche expedition, as well as from those of the Swedish expedition under the leadership of Otto Nordenskjöld (40, 41). Later expeditions have given only a few additional notes.

The work of the author does not afford much new information in a petrographical respect, because the tracts he visited were mainly the same as those dealt with by the foregoing expeditions. It embraces, however, also a number of new localities, and above all tries to give some new data about the structural geology and of the geological connection between the different parts of the southern Cordillera.

In spite of the above-named investigations there are still very large areas which have never been visited before, nor had the present author any opportunities of completing our knowledge of these places. Particularly the ice-covered High-Cordillera north of the NW-arm of Canal Beagle is still a »*terra incognita*». Our knowledge about the land farther east in the populated parts of Canal Beagle, is generally limited to the coast-districts.

In the following chapter the south coast of the Main Island will be described from west to east, as far as the geology is known up to the present.

From the westernmost part of the south coast we possess no certain data at all. Looking from the sea, one receives the impression that the coast-cliffs consist of dioritic rocks. In the inner parts of the fjords there probably already occur sedimentary schists.

The first point from which we have definite observations is Puerto Garibaldi **(30)**, which also was the most westerly place where the present writer made a landing on the south coast. The mountains around Puerto Garibaldi, a fjordlet in which a calving glacier ends, are steep and ice-covered, descending abruptly to the shore.

From this locality — opposite Isla Chaire — Lovisato gives some data about the petrological composition of the coast-cliffs (HYADES, 32). He reports the occurrence of fine-grained amphibole-epidote schists, with quartz and iron-oxide. Farther west he found a granulite (this name he uses for the porphyric types of the granodioritic rocks) generally occurring at the contacts of the Andean diorite with oligoclase, microcline, quartz, biotite, epidote and apatite.

On the west shore of the fjord the present author observed a medium-grained mica-schist with big, black biotite flakes. The rock has a good cleavage, which dips 45° NNE; the rock-types described by Lovisato probably occur farther west. At the same place there are erratics, deriving from the inner parts of the Cordillera, consisting mainly of dark micaceous schists and strongly deformed (»sugar grained») quartzite (Fig. 4, Pl. X); a gneissic rock, which is highly rolled out and schistose, also occurs in abundance.

On the opposite shore of the bay (E), the slopes consist of brownish, weathered sediments, probably micaceous schists of the same kind as those in the locality just described.

Already some km farther eastward the cliffs become grayish and of a more compact aspect, and seem to consist of granitic rocks, or perhaps of granitized schist. The granite occurring on this part of the coast forms, with the schists of the Central-Cordillera, beautiful migmatites with included and partly assimilated fragments of the schists. Assimilation-products of this type occur probably along the greater part of the north coast of the north-west arm of Canal Beagle. They resemble very much Archaian migmatites, and this may be a reason why QUENSEL on his map has marked the coast as pre-Cambrian, although he gives no reason or local description which would account for this characterization (*cfr.* Fig. 32).

The author observed this type of rocks as occurring from the Italia-glacier to Puerto Olla **(31)**.

At the first-named glacier the dominating rock is a fairly pure, gray, slightly mechanically deformed granite. Eastward the amounts of included mica-schist increase; the latter occurs mainly as dikes in the first-named, but is also intruded by the granite. Pegmatite and aplite veins are found in great number.

At Puerto Olla the rock-ground still shows the same composite aspect, though the schistose components are dominant. The granite mainly appears as veins, running partly more or less vertically, partly almost horizontally. The steep cliff on the west shore of the bay offers a splendid profile through the formation. Here the schist is crossed by a network of granitic veins, cutting through the older structure of deformation, and showing that the granite has intruded later than the main folding of the Central-Cordillera. There is no reason to believe that the schists here are of older date than the sericite schists farther west (Jendegaia and Lapataia). They possess the same almost horizontal lamination and the same folding-direction, and consequently

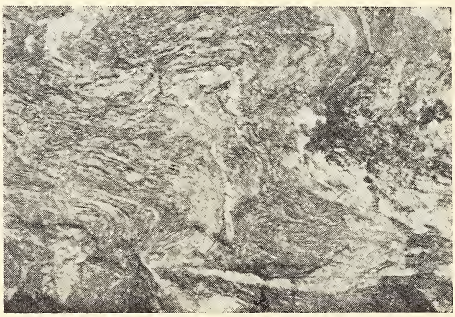


Fig. 32. Folded vein-gneiss. Puerto Olla, on the north coast of Canal Beagle. The sector shown is about 2 m broad.
Foto E. H. K.

underwent deformation in the same cycle of folding. Also in detail the type of deformation is the same, with an intensive differential-folding and riffling, with the folding axes running about E-W, with flat dip.

The sericite schist is also cut by greenstone dikes, which have been influenced by the folding, but, owing to the more resistant composition, they are only broken into brecciated veins (Fig. 33).

The petrological character of the sericite schist has naturally been highly influenced by the intruding granite. It is very rich in quartz, and is, mainly in consequence of the deformation, of a layered structure, with alternate bedding of sericite-rich strata and vein-like strata of pure quartz (Fig. 1, Pl. XXII, p. 127). Red garnet in beautiful idiomorphic grains, often more than 1 cm in size, occurs in great quantities as contact-mineral. It is present in almost every rock-type on the contact of the granites.

The mineralogical composition of the schist is further very simple (Sp. 195) The principal components are quartz, biotite, muscovite and garnet. (Microphotograph Fig. 1, Pl. XXI). Epidote is always present, in the less acidic types in great abundance. As later will be seen (p. 188) this mineral also occurrs in the igneous rocks on the place. The structure is granoblastic, the mineral-components are arranged more or less parallel with the shear-planes. On the other hand the recrystallization was complete after the last shear movements (or contemporaneously), and there is no mylonitic structure visible. Sericite is the dominating mica, and mainly follows the general schistosity of the rock. Between the mica-rich lamellae there are almost pure strata of crystalline quartzite, with slightly undulose quartz. The garnet is crystallized later than the other components, and clearly after the deformation, as big idioblastic grains.

The greenstones in the schists are of amphibolitic composition (Sp. 196). The dominating component is bluish green hornblende with the optical properties of common green hornblende. The extinction is: γ c = 22°. The refraction was determined by immersion

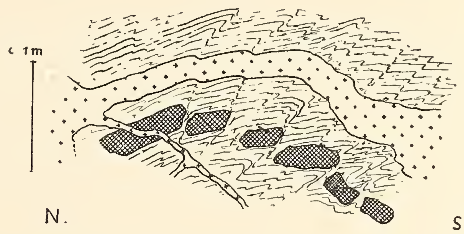


Fig. 33. Dike of cordillera-granite penetrating the deformed central schists at Puerto Olla (north coast of Canal Beagle). The granite is itself in some degree deformed, but has intruded later than the main-folding of the Central-Cordillera.
Crosses — granite, dark shading — greenstone dike.

as β = 1.650—1.651. Other components are light yellowish-brown biotite, plagioclase, quartz, chlorite and titanite. They only occupy about 10 % of the rock. The structure is granoblastic.

The granite is of a rather varying character. It is sometimes strongly influenced by mechanical stress and almost gneissic, in other places it is almost without visible traces of tectonical deformation. Microscopic examination, however, shows that such after all can be proved in every specimen. Beautiful porphyric types are very abundant, showing big phenocrysts of an almost white plagioclase in a mica-rich, generally slightly parallel-striated ground-mass. Especially the boulders in the moraine at the foot of the glacier in the upper part of the valley of Puerto Olla (the Darwin-glacier) consist of a very coarse porphyry-granite, with phenocrysts more than 2 cm in diameter. The petrographical description of this granite will, however, be given later (p. 188).

The rock-ground of Puerto Olla (Anse Gertrude of Hyades) has earlier been shortly described by Lovisato, who observed the occurrence of mica-schist and epidote-bearing amphibolite (Hyades 32, p. 206).

Bahia Jendegaia.

Between Puerto Olla and Bahia Jendegaia, the first big bay east of Punta Divide, the coast-cliffs seem to consist of sericitic schists. No landing was, however, made on this part of the coast, nor do the earlier descriptions give any exact data thereabout.

Jendegaia and Lapataia, the following harbours on the north coast of Canal Beagle, have several times been visited by expeditions, the first-named place being settled. The first to give geological data relating to these places was Darwin. The existing descriptions report the rock-ground to be composed of sericitic micaceous schists: Hyades (32), Nordenskjöld (41). The Swedish Expedition also gives some data about the granites from the inner parts of the Cordillera, which are found in the moraine of the glacier ending in the valley of Jendegaia. Here, as everywhere in the Central-Cordillera, the lithological character of the rock-ground actually makes a rather uniform impression, mainly due to the strong metamorphosis and mechanical deformation, which have given all rocks more or less the same aspect, even when the original composition was different.

Bahia Jendegaia **(32)** lies on the boundary between the central part of the High-Cordillera and the lower, eastern part of the mountain-range, and is the most westerly settled place on the coast. The climatic conditions are here already suitable for sheepfarming. Continuing the bay, a 2—3 km broad open valley extends about 8—9 km in north-westerly direction to the front of a big glacier. The latter, which flows from the west-slope of the mountains of the Monte Bove group, is the source of the water of a fairly broad stream, which in respect of the water-volume is probably the most important of the streams of the south coast of Tierra del Fuego. The Jendegaia valley has on the left hand a branching valley, in the upper part of which there also is a glacier, which, however, does not reach the bottom of the valley.

On the east side of the main-valley is seen an isolated mountain-range, rising to about 800 m. It forms the watershed between the Jendegaia and Lapataia valleys, and has been called Los Pyramides.

The rock-ground. The shore-cliffs on the east shore of the bay consist of sericitic schists, resembling those of Bahia Lapataia.

The lamination forms almost horizontal strata, dipping gently NE or SW (Fig. 40). The axial direction of the numerous miniature folds in the contorted schist varies greatly and gives no certain values of the axial dip. The general slope seems to be easterly (155—160°, dipping about 15°). Schists of this type occur along the whole valley up to the foot of the glacier. On the western shore of the bay, not far from the inlet, there are sericite quartzite, and micaceous schists of in some degree varying aspect. They are more re-crystallized than the former and evidently have been a little more influenced by regional-metamorphosis. They partly consist of green fuchsite-bearing layers. Also calcite-rich strata occur.

Small quantities of sulphides are often seen in the schist, and a couple of small mine cuts have therefore been opened. The ore-minerals are sphalerite, calcopyrite, pyrite and galena.

The geological character of the high mountains, rising south of the Jendegaia valley, is in some degree illustrated by the boulders brought down by the glaciers. The moraines, both the imposing end-moraine and the side-moraines, consist almost exclusively of granite and related rocks. The author collected a great number of types, the most important of which will later be described from the petrological point of view (p. 190). The granite is always at least to some extent influenced by tectonic movements, often it is completely gneissic, with all mineral-components crushed up and rolled out (Fig. 2, Pl. XXXII). Besides the granite boulders there also occurs a white pure quartzite, showing typical tectonized structure (Microphotograph Fig. 2, Pl. XXI). As dark coloured components these contain small quantities of light-green epidote and small quantities of sericite. On the whole, the mineralogy highly resembles that of the rock-ground of Puerto Olla.

In the moraine deriving from the left hand valley there are no granitic boulders. The mountains in this direction consequently seem to be of the same kind as on the coast of Bahia Jendegaia.

Lapataia and the Cordillera North of Lago Roca.

The Cordillera between Azopardo and Canal Beagle is fairly well known, at least in comparison with the western part of the Cordillera. Starting from the north side, two expeditions have carried out geological observations; the first was that of O. Nordenskjöld (1896), who reached the south shore of Lago Fagnano; the other was the Skottsberg expedition (1908), which traversed the northern part of the Cordillera as far as the watershed.

In connection with the geological observations of these expeditions only a description of the petrology of the granites occurring in the Cerro Svea *massif* S of Valle Betbeder has been published. Other data are very scarce, the lack of usable maps also makes it very difficult to locate the observations. The collection of hand-specimens gathered by the expedition, which the courtesy of Professor P. QUENSEL gave the present author an opportunity of studying, nevertheless gives some important data about the geology of those regions, which complete the profile of the Cordillera south of Lago Fagnano.

The first mountains south of the Azopardo-Fagnano valley consist of rocks belonging to the quartz-porphyry-formation. Immediately behind follow (Cerro Verde) highly metamorphosed schists of the same type as have already several times been described from the Central-Cordillera. Judging from the photographs taken by the expedition, they lie in a similar position as the last-named, for instance in the region south of the western parts of Seno Almirantazgo, having a mainly flat schistosity, and are evidently overthrust toward the north.

Petrologically they are sericite schists and greenstone schists with perfect flaky cleavage.

From the coast of Canal Beagle we have, as already mentioned, certain data from the tract of Bahia Lapataia, which has also been visited by all the above-named expeditions. However, the geological data given by these expeditions comprises only short petrographic characteristics of the rock-types, and the author thinks it therefore useful to cite his own observations more in detail, even though they in part repeat the earlier descriptions.

In addition to excursions around Bahia Lapataia and in the tract of Lago Roca, the author made some excursions to the inner parts of the Cordillera in a NE direction from the north-end of the last-named lake.

Topographical data.

The tract in question has been crossed by some explorers, in addition to the expeditions named above, and they have also contributed to our topographical knowledge of the country. The most important of these journeys was that taken by DE AGOSTINI in the year 1913, his route crossing the Cordillera from about the point Valle Betbeder, by Cerro Svea, over the Cordillera Valdivieso to Valle Lapataia and along this valley to the coast of Canal Beagle. The topographic sketch which DE AGOSTINI has published of this traverse forms our principal source of information about the topo-

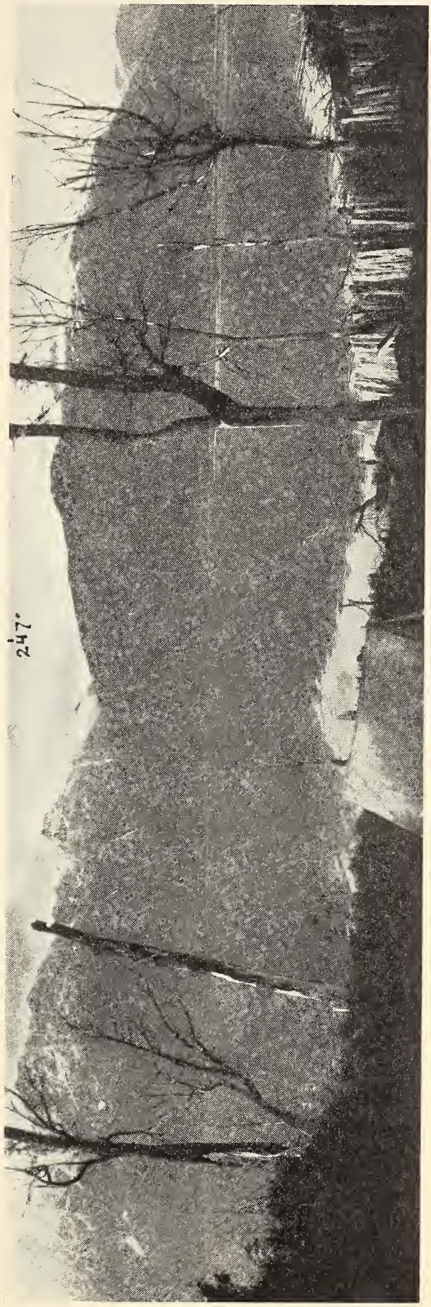


Fig. 34. Steep mountains on the west shore of Lago Roca. The picture is taken almost right angles to the axial-direction of the horizontally overthrust schists. Photo. E. H. K.

Fig. 35. Topographic sketch of the first tributary-valley of Valle Lapataia, reckoned from the outlet of Rio Rojas into Lago Roca. Compass survey by the author.

graphy of the region. No greater degree of accuracy can, however, be accorded to it, as it was made during a strenuous march, which allowed no time for accurate mapping.

The present author had an opportunity of correcting some mistakes in the southern part of the map. — A tributary valley to Valle Lapataia, on the left side, immediately (about 4—5 km) before the outflow of Rio Rojas in Lago Roca is marked on the map of De Agostini. According to De Agostini he crossed this valley near its bifurcation with Valle Lapataia, and he has drawn it as an east-westerly valley about 10 km long, beginning somewhere north of Montes Martial and forming a drainage area behind that ridge. This gives, however, a completely incorrect idea of the first left-hand tributary to the Rio Rojas, reckoned from the outlet.

As a matter of fact, after about 8 km the valley turns rapidly to NNW and runs on as a rather broad, open valley, almost resembling the Valle Lapataia, for at least 10—15 km farther and ends at the eastern foot of the Cerro Svea *massif*, whose imposing summits are visible from the turning-point of the valley. At the latter point there rises a very narrow, about 1100 m high ridge, which separates the new valley from the valleys draining in easterly and south-easterly directions to Canal Beagle. On account of unsuccessful attempts made by his companions to find gold in the valley, the author has named it Valle Desillusion. The highest summit of the last-named ridge, whose white crest is visible from Valle Lapataia, was called Cerro Quensel (about 1300 m), in honour of the geologist of the

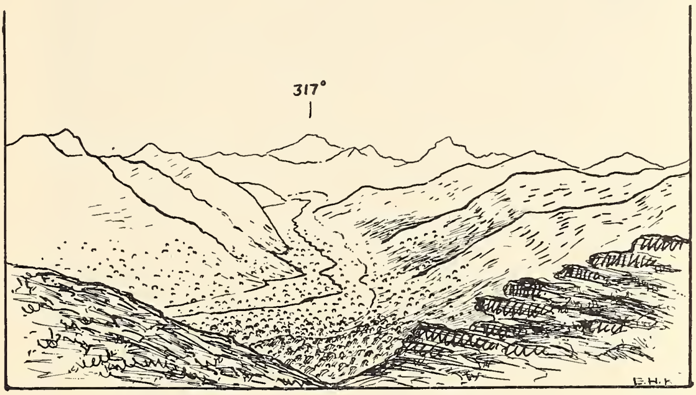


Fig. 36. Valle Desillusion seen from S. In the background the summits of the Cerro Svea *massif*. Sketched by the author.

Swedish expedition, which worked in the region (*cfr.* Figs. 36, 39, and the map, Fig. 35).

It is really very probable that the valley, which the Swedish expedition had in sight from the Valdiviesi ridge (*cfr.* Scottsberg, 51) behind Cerro Svea was Valle Desillusion, and not Valle Lapataia, which is situated too far SW to enable it to be seen from the vicinity of Lago Lövenborg, the final point of the route of the Skottsberg expedition.

Fig. 35 shows a compass-survey of the area NE of Lago Roca made by the author. The distances are controlled by step-measuring and compass. The map shows that the general topographic map of the Cordillera south of the west end of Lago Fagnano will have to be greatly corrected to make it possible to connect it with the area mapped by the author. It may be pointed out that the sketch-map of De Agostini has also been used for the new

American map mentioned above (p. 75). On these maps also Valle Jendegaia is erroneously marked as far too short, as may be seen from the data relating to distances given by the present author in the foregoing chapter.

Valle Lapataia represents one of the most important morphological features in this part of the Cordillera. The lower part of the valley is of considerable breadth (about 2—3 km), and seems to represent a fairly old stage of erosion. Morphologically it is a parallel-valley of about the same character as many of the chief channels of the archipelago (*e.g.* Fjordo De Agostini and probably also the east-part of Canal Beagle (Fig. 41).

Fig. 37. Mylonitic sericite-schist. Bahia Lapataia.
Photo. E. H. K.

The mountains on both sides of the valley do not rise to much over 1000 m nor do they carry any glaciers. In the tributary valley running down from the Darwin Cordillera there are several small glaciers higher up, and on the east side some small tongues have also been observed on Cerro Svea (*cfr.* SKOTTSBERG l. c.).

At the junction with Valle Lapataia, Valle Desillusion is an almost gorge-like cross-valley, cutting right through the axial-direction. The upper part, running WNW-ESE, is broad, and has a comparatively wide valley-plain, covered with dense forest (Fig. 36). Like Valle Lapataia, it is a parallel-valley with steep SW-slope and more gently rising NE-slope.

The northwest-southeasterly direction of the great principal valleys of the cordillera-sector between Cordillera Darwin and Montes Martial is a very characteristic orographical feature, evidently due to the tectonical conditions of the rock-ground.

Geological observations.

At the outlet of Rio Rojas **(33)**, in the vicinity of the old saw-mill, the rock-ground consists of soft greenish-gray chloritic and micaceous schists, showing unmistakeable traces of strong mechanical deformation (mylonitization). They are greatly rolled out and sheared along shear-planes lying more or less horizontally. Metamorphosis has given all the rock-types at this place almost the same appearance, irrespective of their original composition. A closer examination, however, shows that the petrographical character is not

Fig. 38. Crenelated sericitic schist. Bahia Lapataia, N coast of Canal Beagle.

quite so uniform as earlier descriptions (Hyades, Nordenskjöld) have rendered probable. In spite of alteration, the primary structure in many cases is still noticeable, and the original character of the rock can be traced. In that respect the region here in question differs from the inner parts of the Western Cordillera described in the foregoing chapter, where the crystallization usually has destroyed the original structure entirely.

The schists at Lapataia seem to be altered sandstone or graywacke, interstratified with clay-sediments. The silica-percentage is generally comparatively low. The rocks are obviously clastic under the microscope, and

partly also megascopically. Sometimes they are very coarse and conglomeratic. The pebbles are, however, completely crushed up and rolled out into thin lenses. Quartzitic strata are more rarely present, but instead the rock is cut by numerous white quartz-veins, mostly following the shear-planes, and evidently squeezed out from the schists during deformation. They are sometimes rich in pyrites.

The tectonic of the schists of Lapataia is characterized by numerous miniature folds (Fig. 38), in part appearing only as a fine crenelation of the rock; taken as a whole, the layers rest in a more or less flat position, with a slight inclination towards the SW. The average strike is 60—70°.

The same type of rocks were observed all along the east shore of Lago Roca. — In several places there exist small occurrences of sulphide-minerals, resembling those from Jendegaia, which have been subject to prospecting. No find of importance has been made and there are hardly any possibilities of finding ore-minerals in greater quantities in these regions.

At the south end of Lago Roca **(34)** the author climbed the mountain-slopes on the E-side of the valley, above the small »puesto» of Don Antonio, the last settlement in this direction, now that the saw-mill at the outlet of Rio Rojas has been abandoned.

The stratigraphical sequence was here about the following:

The shore of Lago Roca (25 m above the sea-level). Light-gray sericite schist.

230 m. Micaceous schist, rich in dark biotite, and cut by quartz-veins.

400 m. Highly deformed greenstone schist, of ophiolitic origin. The layer lies immediately on the micaceous schist, without any visible contact-influence.

500 m. Phyllite-like micaceous schist, and above the same light-yellowish quartzite-schist, forming also the highest part of the crest (up to 800 m). The folding-axis is about E-W-erly.

Broadly speaking, the rock-ground of Valle Desillusion **(35)** is of the same general character as around Lago Roca. The degree of deformation is about the same, and with a few exceptions also the rock-types are very similar.

In the bottom of this valley, at its junction with Valle Lapataia, a light-yellowish quartzite is found, in which the streamlet has dug a small canyon-like gorge. The rock resembles the quartzite found on the crest above the »puesto» of Don Antonio. The almost horizontal schistosity gives the rock a position greatly resembling an original horizontal stratification. The degree of deformation is, however, strong.

Farther up the valley (about 6 km from the junction) there occurs in the stream-bed a very deformed conglomeratic rock of about the same position and character but very much coarser than the clastic schist at the outlet of Rio Rojas. The pebbles consist of deformed quartzitic schist, possibly of the same material as the quartzite farther down the valley. They often have a length of 10—15 cm. The matrix consists for the most part of big crushed quartz-grains and small astonishingly well preserved crystals of the same mineral. Generally this conglomerate is far less rolled out than the schists at the saw-mill of Bahia Lapataia. This altitude is about 200 m above the sea-level.

The mountain-slope consists higher up of mylonitic schists, similar to that of Lago Roca. They are partly light-coloured quartzitic, mostly biotite-rich

Fig. 39. Cerro Quensel, east of the turning-point of Valle Desillusion. Looking north. Photo E. H. K.

schists, often with enrichment of graphite along shear-planes. The axial-direction is generally about 95°, sloping 10° E.

At the place where the valley curves towards the north, there occurs on the mountain-slope at an altitude of about 800 m a very mylonitized gneissic rock, forming layer-like interfoldings between the sedimentary schists. Down in the valley there is an abundance of loose boulders of the same rock. The structure is very schistose, the colour is yellowish-gray with megascopically visible crushed grains of quartz, felspar and chlorite. At a distance it resembles very much the quartzitic layers of this region. The analysis p. 99 shows that it has a dioritic composition. Fig. 4, Pl. XXXII gives the outer aspect of the rock, which evidently also forms the middle part of the west slope of Monte Quensel.

The summit south-west of Monte Quensel consists of quartzitic schists, farther down there are very deformed micaceous schists, often rich in graphite. They are traversed by almost horizontal shear-zones with slickenside surface, indicating the intense movement in the rock-complex. Between the sericitic and quartzitic schists there are several layers of ophiolitic greenstone-schists (5—10 m thick), occurring as horizontal, slightly southerly sloping eruptive layers, which can be followed several km in the mountain-slope. The tectonic style, which here is characterized by great, almost horizontal movements towards the north and north-west, has a striking resemblance to that of the Pennine Alps. The axial-direction dips gently towards the east, the dip seems to become more steep farther eastward.

The existence of gne ssic rocks infolded in this schist-complex is very interesting, because it proves that there exist in the Cordillera granitic to dioritic rocks older than — or at least of the same age as — the main-folding. It is until further notice impossible to decide if this gneiss belongs to an intrusion completely different to the granite of Cordillera Darwin and Cerro Svea, or is intruded only a little earlier than its main-intrusion, but during the same cycle of intrusion. The geological position seems to indicate that it represents a synkinematic intrusion, which probably began already at the earlier stages of the folding, more or less contemporaneously with the ophiolites. It evidently is the oldest hitherto observed diorite or granite of the Cordillera.

We consequently seem to have an almost continuous intrusion of granodiorites — though probably in several phases — during the folding and overthrusting-movements of the southernmost part of the South American Cordillera.

Petrographic description of rocks from the surroundings of the outlet of Rio Rojas.

Sp. 109. *Mylonitic chlorite-sericite schist.* The shore of the old saw-mill of Lapataia.

Megascopically the rock has a well developed lamellar schistosity. The mineral-grains are composed of flaky minerals or rolled out in thin lenses.

The mineralogical composition of the rock is mainly quartz, altered plagioclase, chlorite, epidote, sericite and biotite. The two last-named comparatively sparsely. The plagioclase is albitic with alteration to epidote and mica. The structure is strongly parallel-schistose, but traces of the original, clastic structure nevertheless are comparatively well preserved. The degree of newcrystallization does not seem to be very high. Of the newformed mineral the mica obviously is formed earlier than the main part of the epidote. Both are orientated along shear-planes. The chlorite is mainly still later and is partly younger than the mylonitization.

Besides the components named above, there is seen a fine threadlike, light-greenish mineral, probably an amphibole, and a black carbonaceous pigment.

Sp. 130. *Mylonitic schist.* The same locality.

The rock is light greenish-gray and soft. The schistosity is very strong. The mineralogical composition is: quartz, plagioclase (partly newcrystallized), chlorite, epidote, talc and titanite. The last-named mineral is altered to leucoxene. The deformation is very strong, but in the fine-grained main-mass of the rock the original grains appear also megascopically as very drawn-out lenses some mm in length. The mylonitization has obviously been stronger than the recrystallization in the rock. The original rock probably was comparatively poor in quartz, and might have been a graywacke.

Sp. 131. *Lime-rich sericite-chlorite schist.* The same locality.

The rock is extremely strongly crenelated and pinched out (*cfr.* Fig. 1, Pl. XIX) and the primary structure is completely destroyed, but evidently the rock once was a mergel-sandstone rich in calcite.

The mineralogical composition is quartz, plagioclase, calcite, zoisite, chlorite and, in rather small quantities, biotite, sericite and leucoxene. Instead of the epidote with high birefraction found in the foregoing rocks we here meet with a zoisite poor in iron. The sequence of newcrystallization is mainly the same as in Sp. 109, which seems to be a general feature of the schists of the region.

Sp. 132. *Mylonite quartzite.* The saw-mill of Lapataia.

The rock is composed of thin layers of crushed, pure quartzite interbedded with marl-like layers of calcite, quartz and chlorite of about the same aspect as the foregoing rock.

Very similar strongly mylonitic rocks occur also around the upper end of Lago Roca. The most typical are the following varieties.

Sp. 117. *Sericite schist* (quartz-phyllite). About 200 m above the rancho of Don Antonio (Microphotograph Fig. 2, Pl. XIX).

Under the microscope the rock shows an intense straightlined lamination, indicating an intense crushing of the mineral grains. The principal components are quartz and mica, and in some degree calcite. The first-named is completely crushed up and very fine-granulated, the second occurs in very fine seams along the shear planes. In addition there is seen a black pigment, evidently carbon, which occurs as thin parallel-bands, probably indicating the primary layering or an earlier shear-direction of the rock. The last -mentioned phenomena is frequently observed in the schists of Lapataia, and shows that the present schistosity in most cases has nothing to do with the direction of the primary bedding.

Sp. 120. *Quartzite schist.* The crest of the mountain, east of the end of Lago Roca. (Microphotograph Fig. 6, Pl. XIX.).

Megascopically the rock is fine-grained, yellowish, with good cleavage along the schistosity, which, however, is not very conspicuous. The degree of deformation is less strong than in the foregoing types. The mineralogical composition is characterized by a considerable quantity of plagioclase and potash-felspar, in addition to the minerals named in the foregoing, this is evidently due to the less advanced alteration. The quartz-grains are partly rounded and possibly primary. They have, like the bigger felspar-grains, generally been slightly rotated at the mylonitization of the rock.

Sp. 114. *Ophiolitic greenstone-schist.* Underneath the foregoing in the same locality.

The rock is megascopically dark-greenish, fine-grained. The original structure is destroyed, and there are probably none of the primary components left.

Under the microscope the rock appears as a rather dull, irregular mass with rounded spots, mainly of epidote, surrounded by light-greenish to colourless mineral-seams, mostly chlorite. There are no primary structural features left, and probably also no mineral components. The present composition is: zoisite, actinolite, chlorite, quartz, and a fine pigment of iron-oxide. Chlorite occurs in comparatively small quantities.

The epidote is light-coloured and has a fairly low index of refraction and ultra-blue interference-colours. It occurs mainly as very small grains, clustered together in spongelike spots. Also the chlorite is light-coloured. The amphibole forms very fine needles, clustered together to a felt-like mass between the other mineral components of the rock.

Valle Desillusion — Monte Quensel.

The rock-types in this region are mainly the same as at Lapataia. The following are worth mention, as representing petrographical features not found in the foregoing types.

Sp. 121. *Conglomerate schist.* The river bed in the bottom of Valle Desillusion (lower).

The rock is megascopically distinctly conglomeratic or agglomeratic, with lense-like, very extended boulders in a fine-grained, mainly quartzitic, ground-mass. Under the microscope the rock shows also in the last-named a clastic structure, with comparatively well preserved quartz and felspar-grains. As is the case with most of the rock-types of this region showing the same degree of alteration, the fine-grained, crushed part of both the ground-mass and the quartz-pebbles are optically orientated in accordance with the deformation, and determination with the aid of a gypsum plate shows that the optical main-axes (ε') on an average are parallel in all the grains. In contrast to this, the big clastic grains possess no such regular orientation, this indicating that they have not been recrystallized during the deformation of the rock.

The dark components seem all to be of secondary origin, and have principally crystallized along the shear-planes. They are: sericite, chlorite and in small quantities epidote. Calcite occurs rather abundantly. In addition more or less idiomorphic crystals of zircon, showing the usual short-prismatic form with pyramidal end-surfaces, are often found as a primary clastic component.

Sp. 126. *Carbonaceous quartzite schist.* The summit SE of Cerro Quensel (Microphotograph Fig. 5, Pl. XIX.).

The rock, which megascopically resembles a light-yellowish schistose quartzite, consists mainly of quartz, calcite and epidote in almost equal quantities, besides an abundance of talc. The rock is in some degree layered with thin bands of carbonate-rich material, alternating with more quartz-rich strata. The quartz-grains are in part crushed primary clastic components, partly recrystallized quartz as in the foregoing specimen. The epidote and talc follow mainly the shear zones, the former lying as rounded grains with high refraction embedded in light-greenish chlorite. Besides, there are seen small needles of brown tourmaline. A brownish oxide-mineral contributes to the yellowish colour.

Sp. 125. *Diorite gneiss.* The summit SW of Cerro Quensel.

Megascopically the rock looks like something between a strongly contorted gneiss and a chloritic schist. The main-mass is yellowish, consisting of quartz and felspar, the dark components are arranged along dense-lying shear zones. The original granitic structure is completely destroyed, and the degree of alteration is mainly the same as in the surrounding para-schists.

Also the microscopical structure is the same as that of a crystalline schist, with the softer minerals, such as chlorite and mica, bending like waves around the crushed and lenseformed, harder grains of felspar and quartz. — The mineralogical composition is: quartz (abundant), felspar (microcline and plagioclase), chlorite, calcite and a black, bluntly needle-shaped oxidic mineral, probably ilmenite. The plagioclase is generally less crushed than the quartz, and the microcline grains are fairly well preserved. It is for the most part altered to zoisite. The chlorite is a clinochlore with low refraction index and strong ultrablue interference-colours.

Microscopic examination gives no definite information about the original character of the rock, and it therefore was necessary to have it chemically analysed. The analysis, which was carried out by Dr. L. Lokka, gives the following result (Table I, an. 1).

TABLE I.

	1	2	Norm.
SiO_2	53.75	54.80	Qz 4.56
TiO_2	2.83	0.84	Or 7.78
Al_2O_3	18.60	18.16	Ab 34.58
Fe_2O_3	2.04	2.34	An 27.80
FeO	6.97	5.47	Bi 5.07
MnO	0.18	—	Hy 10.04
MgO	2.30	4.95	Mt 3.25
CaO	6.98	8.05	Il. 5.32
Na_2O	4.06	3.59	98.40
K_2O	1.32	1.48	
P_2O_5	trace	0.14	
CO_2	0.49	—	
H_2O+	0.76	1.24	
H_2O-	0.07	—	
	100.35	101.06	

1. Diorite-gneiss, Valle Desillusion. S Tierra del Fuego. Anal L. Lokka.
2. Hornblende diorite-gneiss. Tübingen. Rosenburch-Osann, Gesteinsk. p. 674.

Broadly speaking, the composition is dioritic, but shows on the other hand several strange features. The alkali-percentage is rather high, compared with the silica-percentage. Also the content of Al_2O_3 is higher than could be expected, while the MgO-percentage is again lower. These figures prove that the rock does not belong to the ophiolitic greenstones, which are generally recognizable from their high content of magnesia. Apart from the circumstances named above, which may depend on the extremely strong mechanical alteration, the rock has an unmistakable gneissic character, and does not differ greatly from rock-types found among the Andean dioritic rocks (p. 184).

An analysis of a similar diorite-gneiss from another part of the world is given for the sake of comparison. No. 2 is a hornblende-diorite-gneiss from Tübingen, of a completely different mineralogical composition.

The petrographical character of the rocks from the tracts north and northwest of Lapataia resembles that of the rocks from the western Cordillera, as the descriptions given above clearly show (Fjordo Martinez, Fjordo de Agostini, etc.). Also in the present area the schists are all more or less mylonitized and characterized by the new crystallization of chlorite, epidote and sericite. Biotite and likewise the major part of other femic minerals of primary origin are all altered to the foregoing. Calcite is a very common constituent. The recrystallization seems, however, to be less advanced; the metamorphic

---

EXPLANATION TO PLATE XIX.

Fig. 1. Mylonitic sericite-chlorite schist. A strongly altered coarse clastic sediment. Formation of cross shearing is visible. The composition is quartz, albite, mica, epidote, calcite, chlorite and oxides. Outlet of Rio Lapataia. Magn. 15 ×. Nic. ‖.

Fig. 2. Sericite schist with very strong lamellar schistosity and fine-grained mylonitic structure. S end of Lago Roca about 400 m above the sealevel. Magn. 15 ×, Nic. ‖.

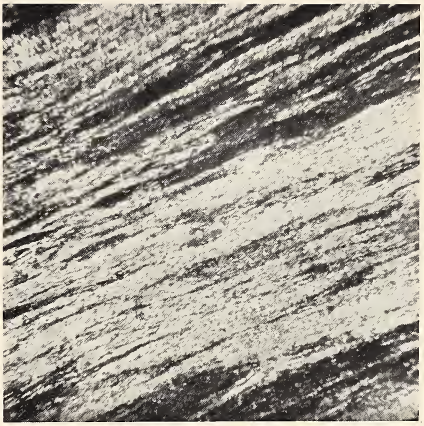
Fig. 3. Carbon-rich, strongly deformed micaceous schist with two generations of shear-planes. The older, which is visible on account of the enrichment of carbon along the moving-planes, is folded and crossed by a younger schistosity. S of Monte Quensel, (Lapataia). Magn. 20 ×, Nic. ‖.

Fig. 4. Mylonite-schist with strong differential-folding. Shear-zone in the highest part of the crest N of Monte Quensel. Magn. 20 ×, Nic. ‖.

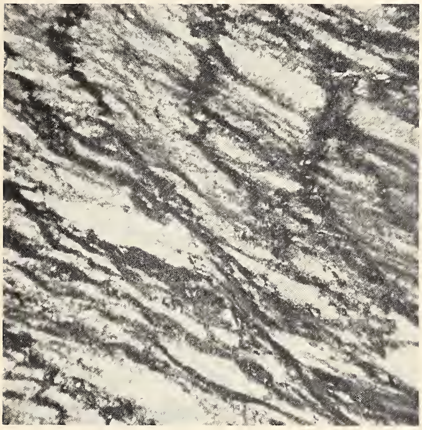
Fig. 5. Talc-carbonate quartzite-schist. The summit S of Monte Quensel. The mineral-components are quartz, talc, calcite, epidote, and in smaller quantities felspar, mica and tourmaline. Magn. 20 ×, Nic. ‖.

Fig. 6. Quartzite schist, with imperfect recrystallization. Bahia Lapataia. Magn. 15 ×, Nic. ‖.

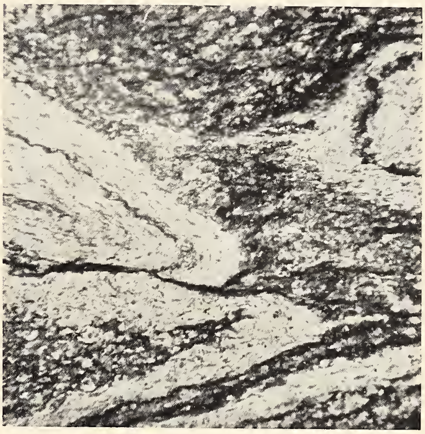
1



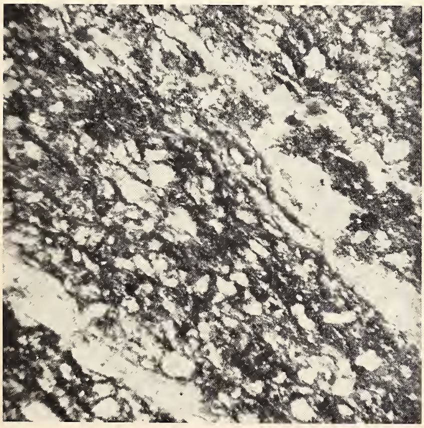
2



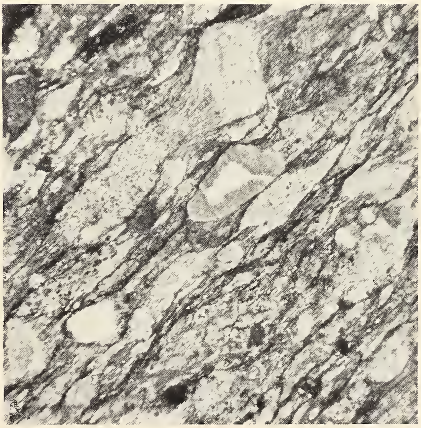
3



4



5



6

Fig. 40. The Jendegaia glacier (Ventisquero Jendegaia). The mountains consist of sericitic schists of the Central-Cordillera. The flat-lying schistosity is well visible in the cliff-wall on the right side of the picture.
Photo. E. H. K.

Fig. 41. The Lapataia valley with steep SW-slopes and gently sloping NE-sides depending on the general southwesterly dip of the schistosity. North end of Lago Roca to the left.
Photo. E. H. K.

components are generally very small-grained, and the orientated crystallization is but incomplete. In some cases the primary structure is recognizable under the microscope, but generally the mylonitic structure dominates. Evidently the mylonitization and chemical metamorphosis took place at a comparatively low pressure.

The intense lamellar-schistosity, conspicuous particularly in rock-types rich in chlorite and mica, is very flat-lying throughout this area, depending on the tectonical style. As nappes of Alpine character, the rock-complex has been driven in a north-westerly to north-north-westerly direction, and obviously for a considerable distance. The overthrusting-movements extend at least for several miles. The sediments with interstratified volcanic rocks have thereby been rolled out in thin layers, almost resembling horizontal strata of a primary layering.

Vertical folds of the type characterizing the less altered schists farther east in the tracts of Ushuaia (see below) are entirely absent. Contact-mineralization has been observed only to a less extent. A mineral which can be interpreted as such are the small tourmaline-crystals of Monte Quensel, which possibly derive from the old, deformed diorite of the region.

The coast between Lapataia and Ushuaia.

The mylonitic, micaceous and chlorite-schists of Lapataia seem to extend about 5 km towards the east. A couple of km west of Bahia San Juan the schist is very coarse and light-coloured. The author unfortunately had no opportunity of examining it more closely, but it is very probable that we here have to do with a strongly altered quartz-porphyry. This rock-type forms only a narrow zone of some hundred metres breadth. Farther eastward the schists gradually become less altered and pass over into phyllitic slate-like rocks, which still are rather schistose but only slightly recrystallized. We here enter the »slate-formation» of the eastern part of Canal Beagle.

In order to avoid confusion with the clay-slate formation of Darwin, which comprises mainly younger sediments of Cretaceous age, it will in the following be called *the Yahgan-formation* after the former inhabitant of the area. This formation comprises the southernmost part of Tierra del Fuego, the easternmost Cordillera of the Main Island, and the major parts of the islands Navarino, Hoste and Gordon.

At San Juan the rock-ground was examined more closely at a small open- cut in a sulphide-rich zone of the slate. There occur in small quantities

the same sulphides which have been mentioned as found at Jendegaia (p. 87). At this place the bedrock is a black slate, rather rich in biotite, crossed by numerous quartz-veins. The strike is 305°, the dip 80° S. The last-named data show that we here enter a tectonic zone, of a type different to that of Lapataia and farther west. Instead of showing an almost flat differential-folded schistosity, the layers are very steep.

Eastward the cleavage of the schist becomes less conspicuous and is of the same character as in the surroundings of Ushuaia.

The rock-ground around Ushuaia **(36)** is petrographically described by NORDENSKJÖLD and HYADES. The present author also had an opportunity of studying NORDENSKJÖLD's collection of rock-specimens from this tract. The most interesting feature observed by the first-named geologists is the occurrence of fossil-remains in the schists. They highly resemble the radiolarias described as occurring in the Monte Buckland-series.

The rock-ground around Ushuaia consists of blackish-gray phyllite-like schists, with a rather irregular splintery cleavage, caused by numerous joints and miniature slopes. The schistosity strikes N 70° W to E-W, the dip is generally steep. The bedding is frequently well visible and has mainly the same strike. The strata are folded in big folds, with more or less vertical folding planes.

According to NORDENSKJÖLD's specimens, the rock on Peninsula Ushuaia seems gradually to change towards the south; the southernmost part of the coast consisting of a fairly coarse, grayish green sandstone or graywacke containing abundant fragments of volcanic rocks. The present author has found the same rock-type on the coast of Canal Beagle, on the northern shore of Isla Navarino (p. 136). The rock is almost unaltered and the folding generally less intense than in the mountains behind the town.

In Montes Martial the rock generally is of the same dense phyllitic type as in Ushuaia, occasionally interbedded with slightly coarser, sandstone-like layers. In addition there frequently can be observed thin carbonate layers, with reddish weathering, and the slate itself often contains an abundance of calcite, and may sometimes be classified as marl. For the most part the schist is, however, poor in lime. In the Montes Martial the schistosity is very pronounced and almost vertical.

The style of folding in the mountain-complex of Montes Martial and the ridges farther north is beautifully visible from the ridges north of Ushuaia. The slates of Monte Olivia and the summits west of this mountain all show the same tectonical appearance. The layers are folded in steep or slightly overturned folds. The different folds are often

cut from each other by slopes (Fig. 42). The folding axis seems generally to be east-westerly and the direction of the deformation from the south towards the north.

In Montes Martial the direction of the folding-axis is 70—90°, dipping 10—20°. The schistosity strikes 270—280°.

The folds are sometimes slightly overthrust, but generally so compressed by the tangential stress that this thrusting is less conspicuous. The tectonic style clearly indicates folding at a rather high level, where the pressure of the overlying rock-masses was low.

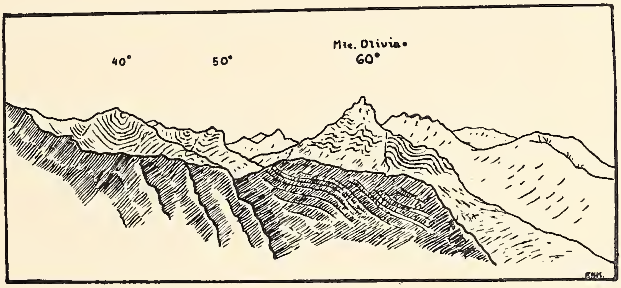


Fig. 42. The folding-style of the sediments NW of Ushuaia seen from Montes Martial. Sketch by the author.

The valley of Rio Olivia (37)

Morphology: The lower part of the valley of Rio Olivia, which flows out E of Ushuaia, is a typical cross-valley, running N-S or at almost right angles to the folding-axis of the Cordillera. As in all the cross-valleys, the topography is very steep, with often almost vertical cliff-walls on both sides of the valley-gorge; only the lower part of it is more open. The landscape is very beautiful, especially in the vicinity of the famous Monte Olivia, which rises right from the bottom of the valley.

The uppermost part of the river has an almost east-westerly direction and flows along the broad and open Valle Carabajal (Fig. 52), which again is a parallel-valley running at almost right angles to the Olivia valley. It is of a character which recalls the east part of Canal Beagle. The drainage is in this valley very remarkable. From its western part the water flows to Canal Beagle through the Olivia valley. Some km east of the junction of the two valleys there is a low watershed on the valley-plain (*cfr.* Fig. 52, p.

XXIII), from which the water flows partly to the west to the Olivia valley, and partly to the south-east along Valle Carabajal, flowing out in the vicinity of Puerto Harberton at the east end of Canal Beagle.

The present drainage-conditions seem consequently to be younger than the original erosion which sculptured the Carabajal-valley. The Olivia valley is evidently formed later, and has eroded backwards through the Cordillera and has cached on part of the waters of Valle Carabajal.

The topography of the uppermost part of the Olivia valley supports such an interpretation. The gorge is very narrow and canyonlike, and obviously rather young. In contrast hereto the erosion of Valle Carabajal makes a very mature impression.

G e o l o g y: From the outlet of Rio Olivia to the small valley-plain below Monte Olivia the rock-ground consists of folded slates similar to those of Montes Martial. The rock is generally phyllitic in character, with a perfect cleavage. Also siliceous sediments are common. It often shows abundance of miniature folds and is cut by numerous miniature slopes and shear-zones. On account of the shear the quartz-veins of the rock frequently have a ptygmatic appearance, reminding one of the ptygmatic folds in Archaian rocks (*cfr.* also the microphotogram Fig. 48 p. 108). Broadly speaking, the schistosity and the degree of recrystallization of the rock seem to increase farther from the coast, indicating that the formation in this direction probably represents a deeper level of the rock-ground. — The folding axis is flat, running 90°. The strike of the cleavage is generally the same and almost vertical; a very good cleavage is also seen in the direction 330°, with a slope of 70° E.

An excellent profile is offered by the steep east wall of Monte Olivia and the mountains on the opposite side of the valley. The strata are folded up in several folds of some hundred metres depth, thrust over to the north.

North of Monte Olivia, where the valley becomes narrow and canyonlike, also the character of the rock-ground changes. It consists of s c h i s t o s e b u t s t i l l w e l l p r e s e r v e d g r e e n s t o n e. The rock is generally medium-grained, greenish-gray. The dynamic metamorphosis is megascopically conspicuous only in certain strikes. The primary supercrustal features are well preserved, in the form of amygdaloidal structure. The bladders are often strongly rolled out. At several places, especially in the valley slope on the west side of the river, there appears a very well preserved pillar-formed jointing, a rather peculiar feature between the strongly folded and schistose rocks of the surroundings, especially as the greenstones themselves, as will be seen later, are in several places extremely pinched out and schistose.

The rock is occasionally strongly brecciated, indicating that it has been influenced by mechanical deformation when already consolidated. The main fissuring and cleavage are the same as in the schists (c 290°).

This greenstone evidently belongs to the ophiolitic intrusions, which here have reached up to the surface and crystallized as an effusive rock. In every case it is younger than the underlying sedimentary strata, and probably also younger than the sediments above.

On the north side of the greenstone mass follows a mylonitic schist, which is extremely tectonized, the primary character being completely destroyed. It may be characterized as a mylonitic sericite-schist and was proved to be a

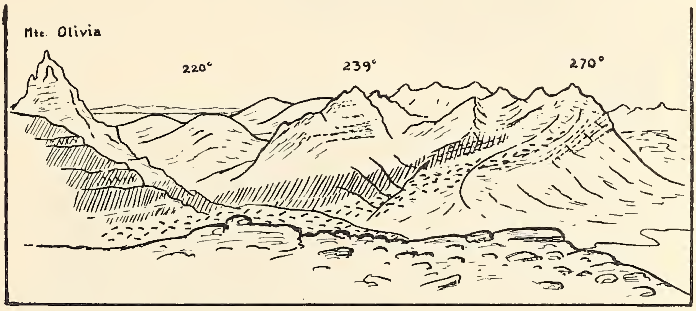


Fig. 43. The situation of the quartz-porphyry mylonite-zone north of Monte Olivia at Valle Carabajal. Dots quartz-porphyry, dashes greenstone. Sketched by the author.

strongly altered quartz-porphyry. There is a striking difference between the degree of metamorphosis of this schist-zone and the slates described in the foregoing. Everything points to the fact that we here enter a zone of very strong movement and mechanical deformation.

The mylonitic zone is about 3 km broad, but seems to pinch out higher up on the mountains (Fig. 43). It was investigated more in detail on the mountain east of the junction of Valle Olivia and Valle Carabajal, N of Monte Olivia.

The north slope of the mountain consists of black slate of the same kind as Monte Olivia, here seemingly composing the base of the mylonites. This rock occurs from the foot of the mountain right up to the crest, 974 m above the sea. (The base of the valley is here 200 m above the sea, the forest-limit 560 m). South of the highest crest strongly tectonized schists are found. Taken from north to south the sequence is the following:

1. black, strongly laminated phyllite,
2. sericitic schist (altered quartz-porphyry and tuff) 100 m,
3. quartz-porphyry schist,
4. mylonitic greenstone (30—40 m),
5. quartz-porphyry schist,

The total thickness of the formation is here 6—700 m.

On the south side lies again greenstone, which is only slightly altered, resembling the greenstone down in the valley. Also here one finds pillarformed jointing and amygdaloidal structure.

Fig. 44. The mountains on the west side of Valle Olivia opposite Monte Olivia. The lower hills in the foreground consist partly of supercrustal greenstone with columnar jointing. The high mountain consists of slate. Photo. E. H. K.

The direction of the strike in the mylonitic schists in generally 80—90°, the dip is 45—60° S. The folding axis is about eastwesterly and seems to slope gently towards the east.

The position of the different layers of the schists north of Monte Olivia is shown on the schematic profile Fig. 43. Regarding the origin of the mylonite zone, it is possible that the slates of Monte Olivia here have been thrust over the schists farther north and on the moving plane the rock has been crushed up. The greenstones have evidently intruded along the less resistant zone of deformation, at the beginning of the movements in the earth crust. They have reached the surface and crystallized as effusive beds before the Monte Olivia complex rode over it. In connection with the mylonitization, possibly together with the effusion of the greenstones, the porphyry-schists

have been enriched in pyrite and chalcopyrite, and are therefore highly oxidized. The brownish-red colour of the weathered surface proves that the mylonite-zone continues also in the mountain-wall on the opposite side (W) of the Olivia valley and trends in east-westerly direction about parallel with the valley.

Unfortunately, the author had no opportunity to visit Cordillera Alvear and to decide if it belongs to the same formation of slaty schists (the Yaghan formation) as Monte Olivia, etc., or if we there have to do with schists of the Central Cordillera type.

The quartz-porphyries of Monte Olivia greatly resemble the more altered of the porphyries of Azopardo and Fjordo Finlandia (p. 81) and might belong to the same horizon.

Petrographic description of the rocks of the regions of Ushuaia and Monte Olivia.

a. The Ushuaia region. The general character of the rock-types in the vicinity of Ushuaia is known from the descriptions of O. NORDENSKJÖLD (41).

The rocks of Peninsula Ushuaia are generally, especially on the southern shore, rather coarse sandstone containing abundant fragments of volcanic rocks of andesitic and trachytoidal aspect, together with fragments of quartz, felspar and pyroxene crystals. This sandstone also contains remains of fossils (foraminiferas?), which, unfortunately are very badly preserved, and impossible to determine.

These rock-types, which evidently are to be characterized as tuffitic sandstones or graywacke, are of wide extension farther south on the islands in the Fuegian archipelago, Navarino, Hoste etc. Ushuaia is the northernmost point where they have been with certainty identified in this part of the country, though some of the schists of the Cordillera north of Ushuaia probably are strongly altered rocks of the same type.

Northward the rock-ground consists of black dense schist. NORDENSKJÖLD describes also andalusite-bearing varieties, indicating a contact-influence of a granitic or dioritic rock, which is not itself visible in the region. As later will be seen, this rock probably is the Andean diorite which occurs on the opposite side of the channel.

From the same igneous complex also the greenstone dikes, named by NORDENSKJÖLD, derive. They have the same aspect as the dikes observed in several localities within the Andean diorite area of the Coast-Cordillera.

The sedimentary rocks of Montes Martial are petrographically in many respects similar to the dark carbon-rich slaty schists, which we have learned to know along the northern margin of the Central-Cordillera (Peninsula Buckland, Seno Almirantazgo). Though they on the field offer a very uniform aspect, a more detailed examination gives several different types (*cfr.* also NORDENSKJÖLD p. 219).

The main types are the following:

1. Fine-grained phyllite, consisting chiefly of clay-materials (Sp. 94). Under the microscope they form a dense mass, in which small grains of

Fig. 45. Deformed carbon-rich slate with quartz-veins of several generations. The older are »microptygmatically» folded, due to differential-movements in the rock. The coast of Canal Beagle at the outlet of Rio Olivia. Magn. 17 ×, Nic. ||.

quartz and felspar can only occasionally be identified. The microscopic structure indicates that the mechanical deformation has been fairly strong; the rock often shows very nice miniature folds. In connection with the deformation there have been formed numerous fissures, filled with quartz-veinlets. They partly follow the sliding-planes of small miniature slopes, partly shear-planes, parallel or subparallel with the schistosity. The last-named are folded more or less contemporaneously with the main-deformation, the first-named have generally a more rectilinear form. In thin-section there is often seen a kind of ptygmatic or rather micro-ptygmatic folding (Fig. 45).

This rock-type sometimes contains layers with traces of radiolarias, though less abundantly than the tuffitic sandstones and the sediment-type described below.

2. Cherty schists. They seem for the most part to consist of quartz and chalcedony, and generally also contain fine sericitic needles and epidote, sometimes also small quantities of calcite. Carbon and iron oxide is always present in a fine pigment, to which the dark colour of the rocks is due. In these siliceous layers there are often seen abundant traces of fossils, which with certainty can be interpreted as radiolarias. — Better preserved specimens of the same kind will be described from Isla Navarino (p. 133—135).

There is often an interbedding of both the slate-types named above, in layers measuring from a few cm to several cm in thickness. Also a banding depending on smaller or greater percentage of carbonaceous pigment is abundant.

3. As already mentioned, there are also carbonatic layers, though they in this complex seem to play a rather unimportant rôle. They are partly almost pure carbonate; sometimes, though more rarely, mergel-like schist. Though carbonaceous sediments are in no wise rare in the Beagle region, they on the whole are of little importance compared with the clay sediments and siliceous sediments. A good deal of the carbonate contained in calcite veins, etc. is probably not of primary origin, but infiltrated later on. As will be seen, the carbonatic sediments farther south are in some degree more abundant.

Petrographic description of rocks of the Monte Olivia Region. In this region petrological investigations have never before been carried out. The most interesting rocks from here are the schists of the mylonite zone north of Monte Olivia, the quartz-porphyries and the ophiolitic greenstones. The phyllites and other sediments do not offer any new additions to the foregoing description.

The quartz-porphyries and related rocks, have in hand-specimen a very variable aspect, mainly because of the different degree of deformation. The rocks are generally strongly schistose, light-gray or almost white coloured, megascopically almost resembling a quartzite. Under the microscope the porphyric aspect is visible. In a dense ground-mass often astonishingly well preserved phenocrysts of quartz and felspar are visible, often also pyrite. The quartz is always undulose. The felspar is for the most part a plagioclase with about 15 % An., but also potash-felspar frequently occurs.

The ground-mass is highly rolled out, with the shear-planes bending around the more resistant phenocrysts. The original mineral-composition is completely destroyed. In the irregular mass there can be seen grains of quartz, sericite and epidote, but the main part seems generally to be a sponge-like mixture of quartz and plagioclase, which is so fine-grained that the different components no longer can be distinguished. Epidote sometimes occurs very abundantly and is one of the principal minerals of the rock, particularly in some felsitic types. Such felsites are often very hard and resistant and have therefore been used by the Canal-Indians as material for stone implements.

The light colour of the mylonitized porphyries and tuffs is probably partly owing to bleaching, due to an oxidation of the pyrite of the rock. The same phenomena can be observed also in the porphyries of the Azopardo-Fagnano area.

Sps. 149, 150 and 152. *Ophiolitic greenstone,* north of Monte Olivia.

The rocks have in very varying degree been influenced by mechanical deformation and therefore afford a good opportunity of studying the different stages of the alteration of the greenstones.

In the less deformed varieties, in which megascopically hardly any parallel structure is discernible, the only trace of deformation is that the plagioclase crystals are crossed by numerous joints and the pyroxene is partly altered. The structure is almost ophitic. The main part of the rock is composed of these two minerals.

The plagioclase is an oligoclase with 25 % An. The composition is consequently more acid than could be expected on account of the basic aspect of the rock, and a tendency to become prasinitic is obvious. The pyroxene is an almost colourless augite. It is only partly fresh, and always very corroded in the outer parts and altered into a thread-like amphibole. $2E = 37°$, $\gamma : c = 43°$.

The coarse fissures which penetrate the main-components are filled up with a light-greenish, seemingly isotropic mass of chlorite together with epidote and light amphibole (actinolite), which give the green colour of the rock. Titanite is abundant, mostly as leucoxene, calcite occurs only sparingly. The rock often contains big amygdules filled with quartz and chlorite. They are sometimes completely rolled out to thin flakes.

In more deformed types the principal part of the rock is altered into a grayish, opaque mass, in which one can distinguish needleformed minerals of different kinds, evidently zoisite, serpentine, and chlorite and also leucoxene in abundance. Irregular crushed grains of albitic plagioclase and quartz, and often great quantities of calcite, are also contained therein.

In the most altered types there are no primary components left, nor hardly any other mineral, which could be determined with certainty. The whole rock has become a dull, opaque, white mass of zoisite, calcite and serpentine, with occasional new-crystallized big epidote crystals.

The composition of the less altered varieties appears from analysis 1. in table II. by L. Lokka.

TABLE II.

I		Norm of I		
SiO_2	48.63	Qz	2.34	Sal 54.74
TiO_2	2.34	Or	1.67	
Al_2O_3	14.85	Ab	25.15	
Fe_2O_3	1.91	An	25.58	
FeO	9.47	Di	8.13	Fem. 45.33
MnO	0.12	Hy	27.23	
MgO	7.93	Mt	2.78	
CaO	7.20	Il	2.78	
Na_2O	2.98	Py	4.41	
K_2O	0.30		100.07	
P_2O_5	0.01			
S	0.21			
H_2O+	4.09			
$H_2O\div$	0.21			
	100.25	III, 5, 4, 3; Auvergnose.		

1. Ophiolitic greenstone. Monte Olivia. Tierra del Fuego. Anal. L. LOKKA. CO_2 0,18.

The high content of water shows that the rock is fairly hydrated and therefore difficult to calculate. The composition corresponds to that of similar greenstone from other Alpine regions. On the other hand, there are no similarities with the rocks of the Andean diorite series, not even with the basic varieties of dike rocks belonging to this group, which proves that the ophiolite as a matter of fact belongs to an independent eruption series. This fact accords well with the geological observations.

THE NORTH COAST OF CANAL BEAGLE EAST OF USHUAIA (Sierra Sorondo).

On this part of the coast the author made only one landing, at Puerto Harberton. The rock-ground, however, so far as can be decided from the ship, consists all along the coast of dark slates of fairly uniform character, with the folding axis generally running about parallel with the coast.

At Puerto Harberton **(38)** the coast already is rather low, the mountains having retired several km from the shore. The surroundings of the farm are covered by thick moraine-layers, which build up small parallel-ridges, striking in about a north-west south-easterly direction.

Outcrops were observed only north-west of the farm near the shore. They consist of black phyllite, rich in carbon, and crossed by white quartz-veins

(Fig. 46). The strike is 80°, dip 45° S. The pitch runs about east-west with a slight dip towards the west.

The boulders in the moraine, deriving from the mountains in the north-west, probably mainly from the region of the Carabajal valley, consist chiefly of rocks which do not belong to the phyllitic slates of the coast area. There

Fig. 46. Black slate of the Yahgan-formation. Puerto Harberton, east end of Canal Beagle.

is abundance of pebbles of a strongly mylonitized gneiss, of the same type as the gneissic boulders found in the moraine around Ushuaia (*cfr.* NORDENSKJÖLD). Further there is a coarse porphyric quartz-porphyry, proving that this rock occurs also in the eastern parts of the Cordillera, probably in the ridges south of Lago Fagnano (Cordillera Alvear). Very abundant are also boulders of greenstone of the type described from Monte Olivia, and deformed and schistose conglomerates and breccias. Boulders of pure quartz are very numerous.

East of Puerto Harberton the Cordillera gradually decreases in height, the snowcovered crests and summits disappear, and the mountains take the character of a tableland, rising to 4—500 m above the sealevel.

5. Review of Geological Conditions in the Central-Cordillera.

According to the local investigations given in the foregoing chapters the regional extent of the high-metamorphic schists of the Central-Cordillera is, broadly speaking, the E and N parts of Isla Clarence (westernmost part of Peninsula Brunswick), Peninsula Sarmiento, Cordillera Presidente Ibanez and that part of Cordillera Darwin which is not occupied by the granitic rocks of the igneous kernel of the range. This granitic kernel is of much greater extent than the earlier geological maps render probable, and runs westward to the neighbourhood of Fjordo de Agostini. On the southern coast-regions of Tierra del Fuego the Central-schists extend up to some km east of Lapataia, in the inner parts of the range farther still.

North of the Central-schists there is a less altered group of sediments occupying the higher parts of Peninsula Buckland, where they rest unconformably on the metamorphic Central-schist, the tracts south of Seno Almirantazgo and around Lago Fagnano. In this group, which has been called the *Monte Buckland formation*, after the most typical and unaltered locality, there can be distinguished two very different rock-types, the first is the slaty schist with chertlayers, the other is a thick series of quartz-porphyries and their tuffs. — The last-named also comprizes the quartz-porphyries of the Azopardo area. Very similar phyllitic slates also occur around Canal Beagle, on the Main Island and the islands of the Coast-Cordillera. They have here been called *the Yahgan formation*. The two last-named contain abundance of micro-fossils, and are in part typical radiolarites. However, the strong alteration makes closer determination impossible, and it seems therefore advisable to use the local name until the age-relations are definitively settled.

The metamorphosis of the Central-schists is generally fairly uniform in the inner parts of the mountain-range. The typical minerals are albitic plagioclase, chlorite, epidote, sericite and quartz, consequently corresponding to the greenschist facies (Eskola, 20, Th. Vogt, 62). They occur within an area which tectonically is characterized by wide tangential movements under probably comparatively light pressure. — In the southern parts of the

Cordillera (S end of Fjordo Martinez) there occur schists characterized by garnet and glaucophane. They are situated nearer to the root-zones of the ridge, and in areas where there is reason to assume contact-influence of the Central-granite contemporaneously with overthrusting movements. — Still farther south there occur in the same area typical amphibolitic schists with green hornblende; these might belong to an older part of the back-zones.

In the Monte Buckland and Yahgan-formations the alteration in the typical areas is generally less conspicuous, and mainly consists in a strong schistosity, without newcrystallizations to any high degree.

The stratigraphical relations of the different formations of the rocks of the Central-Cordillera can partly be cleared up in the region of Peninsula Buckland and Fjordo Finlandia. In the first-named locality the Monte Buckland formation rests disconformably on the Central-schists, with a basal breccia or agglomerate containing fragments from the basal schists. Here it also can be clearly proved that the quartz-porphyries really constitute the undermost part of the formation and do not belong to the basal-schists. This relation has been proved also at several other places.

At Fjordo Finlandia the conditions are more complicated, because the porphyries and related sediments here are overridden and evidently folded together with high-metamorphic schists, and are themselves very difficult to recognize in consequence of strong mylonitization. We can consequently have possibilities of finding infolded rocks belonging to the Monte Buckland series also at other places in the central parts of the Cordillera, and it is therefore incorrect to refer all the Central-schists to series older than the phyllites in the marginal parts of the Central-Cordillera (Bonarelli, Quensel).

According to the present author, the Monte Buckland and the Yahgan formations are of the same age, though we as yet have no absolutely conclusive proof of this. Not only the rock-types and the stratigraphic sequence, but also the existing fossil-remains are very similar. The ophiolitic greenstones are comparatively scarce in these rock-types, probably on account of the position in the mountain-range.

C. THE COAST-CORDILLERA SOUTH OF TIERRA DEL FUEGO.

General Remarks.

From the petrological point of view the Archipelago south of the Main Island of Tierra del Fuego is perhaps the best explored part of the country. We have a great number of observations relating to this region compiled by the Romanche Expedition (Hyades), and also by Lovisato, Nordenskjöld, Quensel, Halle and others (32, 40, 41, 45, 30).

Though the petrological main features of that part of the Cordillera belonging to the Pacific island-zone are comparatively well known, the structural geology still remains at the same primitive stage as that of the other parts of the Cordillera. Also our knowledge of the petrological composition of the rock-ground still needs much completion before the definite map of the country can be drawn. At present there still remain innumerable islands which have never been visited by a geologist, and the interior parts of the great islands of the archipelago are with few exceptions still a »*terra incognita*».

The author had no opportunities to make more detailed investigations in this part of the Cordillera. Nevertheless, as he believes that every new observation is of importance, also landing points where the observations made are only sporadic, without connection with the whole, will be described in some detail.

The part of the archipelago visited by the author consisted of Isla Gordon, Peninsula Dumas (Isla Hoste), Isla Navarino and some of the islands in the archipelago farther west.

Of these islands Isla Navarino is partly settled, with some small »estancias» along the coast. On Peninsula Dumas some small »puestos» are also established, but Isla Gordon and the other islands of the archipelago are still unpopulated, owing to the bad climatic conditions.

Isla Gordon.

The North Coast.

Two landings were made on the north coast of the big island Isla Gordon: 1) at Bahia Tres Brazos (Three Arm bay) in the western part and 2) in the small bay between Bahia Romanche and Punta Divide, opposite the Romanche glacier. This small bay is not marked on the charts, but is evidently identica with Hyades' Bahia Cascada.

The coast is steep, ascending rapidly to an altitude of a few hundred metres. Only around the first-named bay are there small open valleys. Bahia Romanche and Bahia Cascada are both surrounded by steep snowcovered mountain-crests. The inner parts of the island are glaciated all over.

The rock-ground of this coast differs in composition from the opposite coast of Canal Beagle described earlier (p. 83). Here we again meet with rocks resembling the slaty schists of East Beagle, although the deformation is slightly stronger. Also the tectonical condition is in the same way characterized by comparatively gentle folding, owing to which the original composition and aspect of the sediments is only slightly altered.

At Bahia Tres Brazos **(39)** the cliffs west of the inlet seem to be composed of diorite. The opposite point (NE) consists chiefly of sedimentary rocks, noticeable by their reddish-brown colour, sharply deviating from the grayish colour of the dioritic rocks on the opposite coast. The style of folding is clearly visible in the small summit south of the point as simple, almost vertical, folds in the well stratified sediments.

On the shore the schists appear to consist of strata of several different rock-varieties. Alternating layers of greenish-gray phyllite and dark fine-grained quartzite were observed right at the point, the different layers attaining a thickness of about 1—2 m, sometimes also less. Between these sedimentary strata there occur beds of fine-grained greenstone, mainly forming layer-dikes, but possibly also thin effusive beds.

Farther north of the western shore of the bay the same kind of sediments can be followed at least 3 km. In several places dikes or layers some metres thick were observed, and consisted of a medium-grained, porphyric rock with big, white phenocrysts of plagioclase, and clear, well preserved quartz-grains. In spite of being less altered, they seem to correspond to the dike-rocks in the Central-Cordillera (Sp. 212, Fig. 2, Pl. XXII).

The sediments of Bahia Tres Brazos are more schistose than the slates around the eastern parts of Canal Beagle. The mechanical influence is stronger, but the recrystallization still comparatively insignificant. The axis of the folding generally strikes SE—NW, and consequently does not coincide with the coast line and the direction of Canal Beagle. It points towards Puerto Garibaldi on the S-coast of the Main Island (p. 83), and it is very probable that the brownish weathered micaceous schists of that locality belong to the same formation.

Microscopic description of the principal rock-types of Bahia Tres Brazos.

Sp. 207 *Black phyllite with strong cleavage.* The inlet (E-side) of Bahia Tres Brazos. The visible mineral-components mainly consist of felspar and quartz. They are,

however, strongly crushed up and rolled out, and the main-mass of the dense matrix is impossible to determine. The structure shows a strong parallel-orientation. Calcite is present in rather large quantities in the form of a fine pigment scattered all over the rock. Fine powdered carbon is likewise abundant and is responsible for the dark colour of the rock. It is mainly restricted to the cleavage-plains which here seem to coincide with the direction of the primary bedding.

Sp. 208. *Black phyllite with less conspicuous parallel-structure.* E-shore of Bahia Tres Brazos (Microphotograph, Fig. 4, Pl. XXI).

The rock is megascopically very fine-grained, and appears under the microscope mainly as a very dull mass in which a few occasional well preserved grains of quartz and felspar are visible. In spite of the strong schistosity there are several features which recall the slates described from East Beagle, and sometimes small light spots, very drawn out and crushed, which might be traces of radiolarias. It is, of course, impossible to find any certain indications.

Compared with the sedimentary rocks, the volcanic components in the rock-complex are fairly well preserved. Besides the hornblende-porphyries belonging to the Andean dioritic rocks, the following types are the most important.

Sp. 213. *Metabasalt.* Bahia Tres Brazos, (Microphotograph, Fig. 5, Pl. XXI).

The rock is megascopically very fine-grained, dark-greenish, with amygdules filled with white quartz. The parallel-structure is in the hand-specimen almost imperceptible. — Under the microscope the rock is shown to be fine-ophitic, with small almost clear needle-like plagioclase crystals in a matrix of green chlorite or iddingsite. The composition of the first-named is 32—33% An. In addition there are abundant small black grains of ilmenite. — The rock is penetrated by small veinlets filled with quartz and calcite.

The comparatively unaltered condition of the rock seemed to make it suitable as material for analysis. First the quartz of the amygdules was removed, and places without carbonate veinlets picked out. None the less, the analysis carried out by Dr. Lokka shows that the disintegration is after all rather obvious (1. Table III).

Table III.

	1.	2.
SiO_2	57.60	60.20
TiO_2	1.92	2.01
Al_2O_3	15.64	16.34
Fe_2O_3	0.50	0.54
FeO	6.61	6.91
MnO	0.19	0.20
MgO	3.69	3.86
CaO	4.87	2.39
Na_2O	4.24	4.44
K_2O	0.21	0.22
P_2O_5	trace	—
CO_2	2.01	—
S	0.11	0.12
H_2O+	2.61	2.71
H_2O-	0.06	0.06
	100.26	100.00

1. Metabasalt. Bahia Tres Brazos, Isla Gordon. An. L. LOKKA. 2. The same analysis recalculated.

The rock has a rather high content of CO_2, which renders the calculation of the norm difficult, the Ca — percentage being too small to bind all carbon-dioxide. We should in such a case get in the norm 4.69 % corundum. Even if the alumina-content has increased owing to the origin of chloritic minerals this seems to be very unnatural. It is therefore necessary to calculate one part as magnesite. No 2, Table III, shows the composition of the analysis if all CO_2 is calculated as $CaCO_3$, and this percentage be drawn from the rest and calculated at 100%. The remaining CaO appears to be too small in comparison with the MgO, and it is therefore probable that the carbon-dioxide is not only present in the carbonate-veinlets, but also in the main-mass of the rock, as dolomite or magnesite.

Broadly speaking, the composition corresponds fairly well to a rather acid basalt.

Sp. 212. *Quartz porphyrite*, Bahia Tres Brazos, Isla Gordon. Fig. 2, Pl. XXII.

The rock is medium-grained with light phenocrysts of plagioclase about $^1/_2$ cm in size and smaller grains of quartz, in a greenish-gray ground-mass. The rock occurs as layer-dikes some metres in thickness and has at least in some degree been influenced by mountain folding.

Under the microscope the rock appears to be hydrothermally influenced in a considerable degree, but not schistose. The plagioclase-phenocrysts are often replaced by aggregates of epidote-crystals. Also less altered grains always contain epidote and sericiteseams in abundance. The composition is 41—43 % An. The mineral does not show much zonarstructure, but as a rule twinning according to the Carlsbad-, albite and pericline-laws. In some cases the plagioclase grains are completely altered to epidote, which occurs as polysynthetic aggregates within the old boundaries of the original plagioclase crystals. The quartz-phenocrysts are always rounded and resorbed, but clear and uncrushed. The ground-mass consists of plagioclase, quartz, epidote, sericite, calcite and chlorite, and small quantities of pyrite.

The rock is difficult to place within the groups of eruptive rocks described from Tierra del Fuego. The composition corresponds to the contact-facies of the Andean diorites, but the degree of alteration resembles more that of the old dike-rocks in the central-schists. Probably it is connected with the oldest granitic rocks of the Central-Cordillera, or is deposited between the intrusions of this rockgroup and the Andean diorites.

A type which completely corresponds to the dike-rocks described by NORDENSKJÖLD (41) from Ushuaia, and belongs to the Andean diorite-series, is represented by the following specimen (*cfr.* also p. 176).

Sp. 105. *Hornblende porphyry*. Sill in phyllite, Bahia Tres Brazos.

Megascopically the rock is fine-grained, greenish-gray with small black phenocrysts of hornblende. Under the microscope there appear in the ground-mass chiefly granular felspar and some quartz and carbonate. Epidote and pyrite are present in abundance, titanite occurs rather sparingly.

Hornblende occurs as irregularly scattered, elongated phenocrysts with particularly the prism-surfaces well developed. Other surfaces are mainly 001,010 and 001. The colour is brownish-green. The mineral is of zonar-structure, with the marginal part darker than the kernel. In the last-named $\gamma : c = 19°$.

Farther east from Bahia Tres Brazos we have some geological data from Puerto Voilier. Here HYADES (32, p. 146—147) found schists con-

sisting of quartz and amphibole, amphibolite and in addition some garnet-bearing schists. These rocks probably belong to the same formation as the sediments at Bahia Tres Brazos. The content of garnet indicates that they have been influenced by contact-metamorphosis.

Bahia Romanche has been visited by SCOTTSBERG's expedition but it has not given any data relating to the composition of the rock-ground.

The next locality from which we have exact data is Bahia Cascada **(40)**, visited by HYADES and the present author. The bay affords an excellent example of glacier-sculpturing. It consist of two cirque-valleys, one higher and one lower, the latter being situated below water-level, and forming an almost round lagoon with narrow inlet and very steep cliff-walls, rising to about 400 m above the sea-level.

The rock-ground consists exclusively of a medium-grained, pure diorite of comparatively basic composition. The outer aspect of the rock is the same as that of the diorites from the islands farther west. It is penetrated by joints in a horizontal and another in almost vertical direction, but otherwise shows megascopically no traces of mechanical stress. The microscopical character appears from the description p. 166.

The rock differs greatly from the granitic rocks described from the north shore of Canal Beagle (Puerto Olla, Ventisquero Italia, p. 166) and must be regarded as a typical Andean diorite.

At Punta Divide there again occur sedimentary rocks which have been described by HYADES and LOVISATO (32, p. 149). They seem to be of the same kind as the schists of Bahia Tres Brazos. Here there is consequently a very great contrast between the migmatitic, strongly altered rocks at Puerto Olla, opposite Punta Divide, and the sediments on the east point of Isla Gordon. It can hardly be othervise explained than under the assumption of a slope or tectonical unconformity.

The South Coast.

From the southern coast of Isla Gordon we have exact geological data only from Bahia Fleurais **(41)**, where the present author made a landing. Between this bay and Punta Divide the coast seems to consist of sediments.

Like Bahia Cascada, Bahia Fleurais is a glacier-sculptured bay, and, like every bay of this type observed by the author on the S-coast of Tierra del Fuego (*cfr.* p. 140), it has two sections (lagoons), of which the innermost probably corresponds to the upper »cirque» of Bahia Cascada. The shape appears from Fig. 40 p. 120. Inside the bay there is a narrow two-branched

valley, both branches ending in glaciers. The mountains on both sides are icecovered down to 700 m. The forest-limit here lies at only 3—400 m (Fig. 48).

The r o c k-g r o u n d at this locality is interesting because the sediments here are penetrated by intrusive rocks belonging to the Andean diorites. The 3—400 m height on the E-side of the valley consists of coarse hornblendite, hornblende-gabbro and diorite. The more acid components penetrate the basic rocks in a network of broad dikes and veinlets, or surround often angular fragments of these rocks. The wall therefore gives almost the impression of a volcanic breccia, though there is no doubt that all the rocks derive from

Fig. 47. The glacier-sculptured bay of Bahia Fleurais on the S coast of Isla Gordon. Looking S. Photo. E. H. K.

the same magma. The more basic parts have, however, as a rule crystallized earlier, and are penetrated and partly assimilated by the more acid parts.

Besides this, there are also numerous younger dikes with sharp contacts towards the country-rock. They generally are porphyric with small hornblende needles and white plagioclase phenocrysts, and resemble the dike rock described from Bahia Tres Brazos. Also a micro-gabbro was observed, of eugranitic structure, and containing brown, basaltic hornblende.

The same type of rocks also occur in the inner part of the bay. In the valley at the back they were observed up to a height of about 200 m.

The mountain-complex between the two branching valleys consists of dark slaty schist. As a rule it is more siliceous and of another aspect than the slates on the north coast. It generally shows a primary layering of carbon-rich phyllite and clastic quartzite-schist. Eastward the rock gradually changes into pure quartzite.

On the west side of the principal valley the slopes are composed of almost pure white crystallized quartzite. At the junction of the valleys the contact between the gabbro and the quartzite can be studied. The first-named penetrates the latter, forming a typical assimilation-contact, the gabbro containing resorbed inclusions of the quartzite.

The sedimentary layers are strongly folded and have an almost vertical position. They are in considerable degree deformed, and have an irregular, splitty jointing. The direction of the folding axis seems to be about north-west south-east.

Fig. 48. Bahia Fleurais on the south coast of Isla Gordon. The mountains on the right side of the valley consist of gabbro, on the left side of argillitic schists and quartzite. Photo. E. H. K.

At the foot of the glacier in the valley to the right the moraine contains boulders of both the rock-types described above, and also more metamorphic schists, sericite-quartzite, micaceous schists etc. This proves that in the mountains farther west on the island the formations grade into rock-types more resembling those of the Central-Cordillera. It is as yet impossible to decide if this depends on the different age of the rocks, or only on the vicinity of the great granite-regions of the Coast-Cordillera.

The sediments of Bahia Fleurais evidently belong to the same formation (the Yahgan formation) as the sediments of the north coast, but they are in some degree more altered.

On his geological map BONARELLI (11) marked the sediments of the western parts of Isla Gordon as belonging to the schists of the Central-Cordillera, and the sediments described above as belonging to a younger group, together with the slates of East Beagle (Jura?). Up to the presente day there are, however, no definite proofs of this assumption; to the author it seems equally or even more probable that we here have to do with the same schists in different stages of alteration.

The petrography of the eruptive rocks at this place will be treated together with the Andean diorites p. 167.

PENINSULA DUMAS (ISLA HOSTE).

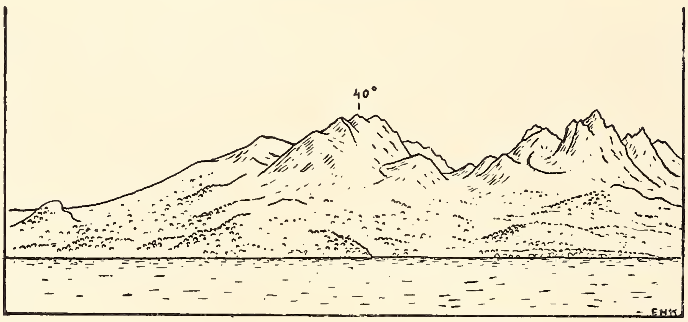


Fig. 49. The steep diorite-summits of Montes Sampaios on the north coast of Peninsula Dumas (Isla Hoste). Sketched by the author.

Like most of the islands of the archipelago of Tierra del Fuego, Peninsula Dumas, the north-western part of Isla Hoste, is an unapproachable highland with summits surpassing 1,000 m.

The peninsula has been visited a couple of times by scientific expeditions, and several rock-types, especially from its easternmost part, the coast of Canal Murray, have been described in detail by HYADES (32). From the northern coast the data are very scarce. Our knowledge of its geology is mainly derived from the data supplied by LOVISATO (32). Unfortunately, the localities of the rock-specimens he collected are so uncertain that they give no exact idea of the general geology. Particularly interesting is his observation of the occurrence of dioritic to granitic rocks on the north shore of the peninsula. — This occurrence of Andean diorite is not marked on QUENSEL's geological map. — LOVISATO also reports amphibole gneiss and amphibole schist and several microgranulites (diorite-porphyries).

On the north coast of Peninsula Dumas the present author made three landings. The easternmost of those was in the small bay east of Peron Cove, below the highest part of Montes Sampaios, the main-ridge of the peninsula **(42)**. This mountain-group is remarkable for its steep and vast forms with sharp summits and crests (Fig. 49), and is distinguished from the more rounded and even crests of the mountains farther east by its almost Alpine character. Already from a distance it appears that the east part of Montes Sampaios must consist of eruptive rocks.

On the shore of the bay named above the rock as a matter of fact consists of diorite, of the same kind as at the south-parts of Isla Hoste. It is evidently the »granite» mentioned by LOVISATO. There is also on the islands outside

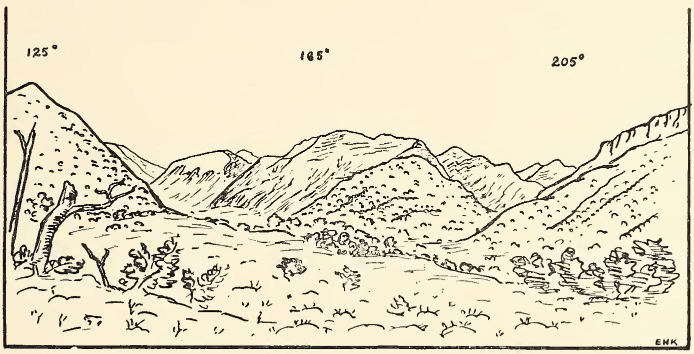


Fig. 50. The topography of the inner parts of Peninsula Dumas S of Bahia Samsing. The mountains consist of dark slates. Sketched by the author.

the bay a schistose rock, which has undergone a very strong contact-alteration and has changed into migmatitic gneiss with garnet.

The diorite at this place is very differentiated, ranging from gabbro with basic plagioclase to quartz-rich granodiorite.

The same rock-types were further found in the vicinity of the second landing-place (Peron Cove), almost direct South of Jendegaia, in a broad valley, whence a rather big streamlet issues [*cfr.* the map **(43)**]. Here is found a medium evengrained, pure gray diorite, with megascopically visible, almost black hornblende crystals and white plagioclase.

The microscopic aspect of the rock appears from the description p. 168.

The westernmost landing was made in a small bay about WSW of Jendegaia (No. **44** on the map) by the author called Bahia Samsing. From this bay a

broad valley runs in about north-southerly direction. It was followed up to about 4 km from the coast. Here it branches into two side -valleys (*cfr.* fig. 50 p. 123), of which the easternmost seems to cross the peninsula from the north coast right to the south. Thick peat-bogs cover the valley-flat; only the lowermost parts show dense wood of typical rainbush-character. (At the foregoing landing-point the bush more resembled the forests of the eastern parts of Canal Beagle, though it already was rather low-growing, and chiefly seemed to consist of evergreen *Nothofagus betuloides*).

The surrounding mountains reach to an altitude of about 5—600 m. They have even crests of almost plateau-like shape.

The rock-ground on the east-point is composed of a peculiar, very coarse gabbro-like rock of ultrabasic composition, consisting chiefly of very big (2—3 cm) somewhat altered amphibole-crystals, with poicilitic plagioclase-inclusions. It probably belongs to the ophiolitic greenstones, or to the later basic dikes of the same series. — Farther north the gabbro rock alternates with phyllitic schists. The last-named are penetrated by the former. The contact is unsharp, indicating that the penetration had taken place at a comparatively greate depth below the surface of the earth.

The schists are partly black phyllites, partly almost white quartzite-like rocks, which under the microscope turn out to be very altered felsitic quartz-porphyries or porphyry tuffs of the type described from the northern parts of the Cordillera. They are highly mylonitic and differs sharply from the gabbro, which is almost unaltered — at least mechanically.

Farther east — higher in the sequence — there occurs a grainy sericitic schist, with occasionally well preserved phenocrysts of quartz and felspar (Fig. 3, Pl. XXII). This is a quartz-porphyry-schist of completely the same kind as the corresponding rock described from Monte Olivia (p. 105). The felsitic schists at this place are evidently tuffs belonging to the same porphyry.

Quartz-dikes, often with a thickness of more than $^1/_2$ m, are very abundant. Here, as in every other place where they have been observed in more schistose rocks the quartz-porphyries contain fairly large quantities of pyrite. The strike of the schists is 315°, the dip 50° S.

The degree of alteration of the schists on the north coast of Peninsula Dumas is generally more conspicuous than in the slates of Canal Murray on the east coast. The mylonitization is partly very strong, but not as strong as on the opposite north shore of Canal Beagle, and there is still almost no recrystallization.

It seems therefore to be very probable that we at Bahia Samsing are almost on the contact between the Central-schists of the Darwin-Cordillera and the Yaghanformation, and it is an interesting fact that this contact also here is followed by the quartz-porphyry-zone, in the same way as we have seen on the north side of the Central-Cordillera at Monte Buckland, Fjordo Finlandia and Seno Almirantazgo.

The schists are penetrated by a younger basic dike, crossing the schistosity, with sharp chilled contact towards the country-rock. It probably belongs to the lamprophyric dikes of the Andean diorite series.

The quartz-porphyry-mylonite also occurs in the cliffs farther up the valley, about 600 m from the shore. The mountains on both sides of the valley seem to consist mainly of phyllitic schists, which also form more than 80 % of the boulder material of the river-gravel. In the southernmost part of the valley, some km SE of the bifurcation, the mountains differ from the brownish phyllite cliffs in its north part, being light gray in colour, and evidently already here consisting of diorite.

The microscopic character of the rocks of Bahia Samsing.

Sp. 182, 183, 188. *Quartz-porphyry schist.* Bahia Samsing, North coast of Peninsula Dumas.

The rock resembles under the microscope the porphyries of Monte Olivia (p. 109), but is partly still more mylonitized (Microphotograph, Fig. 3, Pl. XXI).

In the more altered types the primary minerals are completely crushed up and altered into a quartzite-like matrix containing sericite and zoisite in abundance. The shearing is strong and is under the microscope visible as crush-zones with abundant pyrite and iron-oxide, and occasionally a prehnite-like mineral.

In the less altered types the phenocrysts are still visible. They are mainly quartz, perthitic potash-felspar and zoisitized plagioclase.

The sedimentary rocks at this place are for the most part common phyllites and do not offer anything of particular interest.

No. 177. *Coarse-grained gabbro.* West part of Bahia Samsing, North coast of Peninsula Dumas.

The rock is megascopically coarse-grained, dark greenish-gray. The structure resembles the ophitic, with short plagioclase crystals in a ground-mass composed of very big amphibole-crystals, often 2—3 cm in diameter, in which the smaller plagioclase lathes are poikilitically included. Epidote and leucoxene occur likewise as principal components.

The amphibole forms about 80 % of the rock. It is almost colourless to light-yellowish. The light-refraction was determined (immersion) to $n\gamma = 1.637$ pointing to a CaO-rich variety (tremolite). The boundary between the amphibole and the plagioclase is very uneven and sinoid, the first-named grow as fringes in the latter. It is evident that the amphibole is secondary, probably of uralitic character. The plagioclase is fairly clear, and shows twinnings according to the Carlsbad- and albite-laws. It is in

some degree zonar-built, with a more albite-rich outer zone. The composition is 33—36 %. An. The epidote forms at least 7 % of the rock. It has often sharply euhedral crystals. The mineral is colourless, with high bi-refraction. It is of importance that the amphibole-fringes also grow into the epidote, and the uralitization consequently is still younger than this mineral, which itself was probably the latest of the primary constituents to crystallize. Leucoxene occurs only in small quantities.

Sp. 181. *Lamprophyric dike-rock* penetrating the phyllite. Bahia Samsing, North coast of Peninsula Dumas.

The rock is fine-grained, dark-greenish, with black needle-shaped phenocrysts of hornblende in an almost dense ground-mass. The mineralogical composition is: brownish hornblende, plagioclase, quartz, calcite, biotite, magnetite and titanite.

The hornblende occurs as crystals, in part large (1—2 mm) with sharp idiomorphic form of the habit usually found in the dike-rocks belonging to the Andean diorites. γ: c = 17°. The absorption is γ (grayish-brown) $> \beta > \alpha$ (light-brown). The outermost zone is grass-green. The plagioclase and quartz are allotriomorphic and form, together

---

EXPLANATION TO PLATE XXI.

Fig. 1. Venitic micaceous schist. The minerals are muscovite and sericite in parallelorientation between layers of oligoclase-albite, quartz and epidote. The recrystallization is very complete and evidently is contemporaneous with the deformation. Puerto Olla, opposite Punta Divide, Canal Beagle. Magn. 20 ×, Nic. +.

Fig. 2. Quartzite with strong parallelorientation and epidote (fine-grained) along the moving-zones. Complete recrystallization without undulation in the quartz. Boulder in the moraine of the Jendegaia-glacier on the N-coast of Canal Beagle. Magn. 33 ×, Nic. +.

Fig. 3. Deformed quartz-porphyry. Newcrystallization of quartz in the cavity between two phenocrysts which have been forced away from each other at the deformation. N-coast of Peninsula Dumas. Magn. 25 ×, Nic. +.

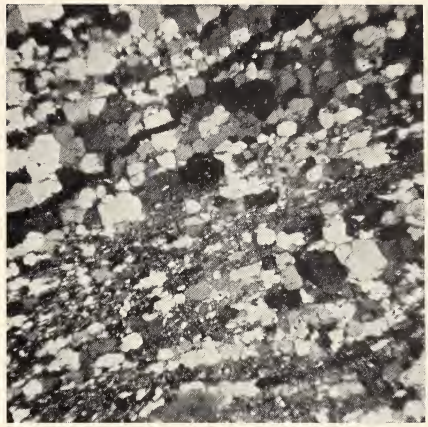
Fig. 4. Deformed carbon-rich slate. The smaller of the white lense-like spots are probably rolled-out radiolarias. Bahia Tres Brazos, N-coast of Isla Gordon. Magn. 14 ×, Nic. ||.

Fig. 5. Metabasalt. Layer between argillitic schists. Bahia Tres Brazos. Isla Gordon. The main components are plagioclase, chlorite and iron-ore. Magn. 20 ×, Nic. ||.

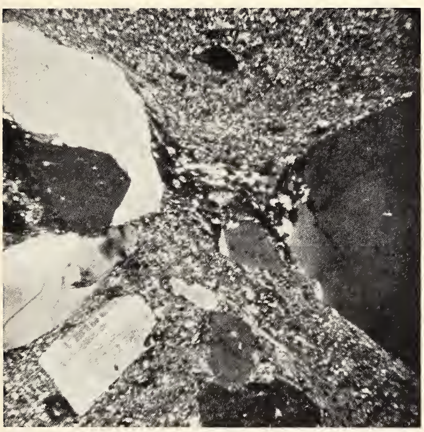
EXPLANATION TO PLATE XXII.

Fig. 1. Vein-gneiss, Puerto Olla, N-coast of Canal Beagle.
Fig. 2. Diorite-porphyry. Bahia Tres Brazos, Isla Gordon.
Fig. 3. Mylonitic quartz-porphyry, Bahia Samsing, N-coast of Peninsula Dumas.
Fig. 4. Hornblende gabbrodiorite, Puerto Santa Rosa, N-coast of Isla Navarino.

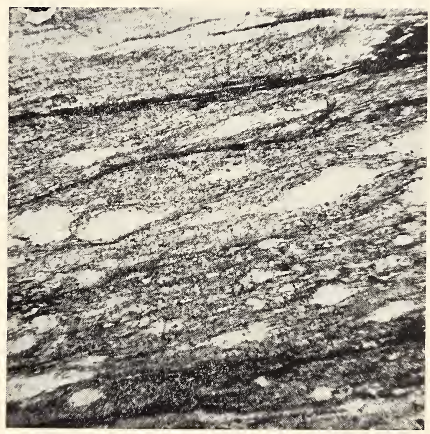
1



2

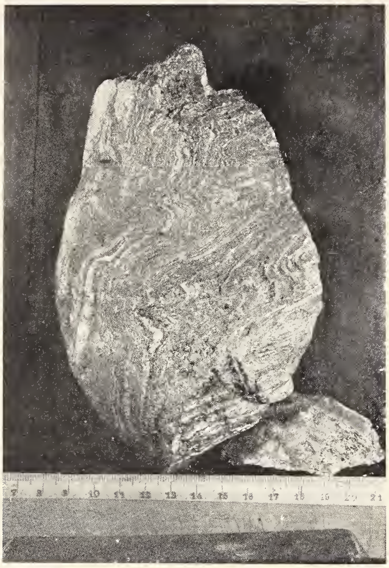


3

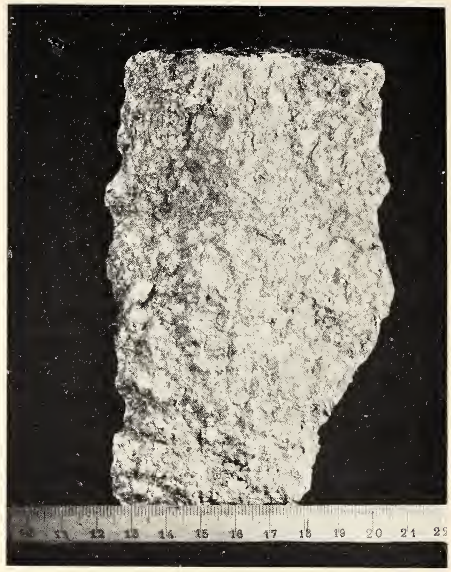


4

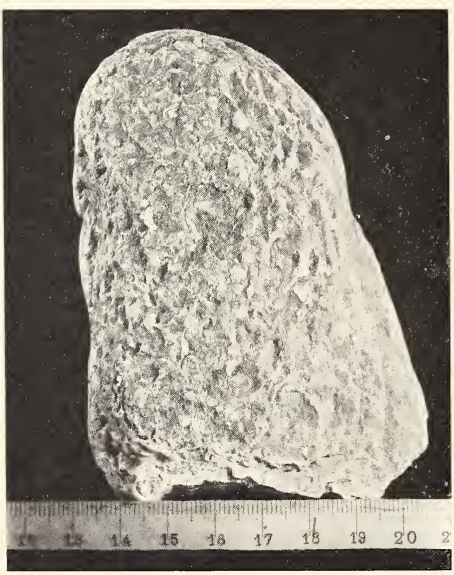
5



1



2



3

4

with small hornblende grains, the main part of the matrix. B i o t i t e in yellowish-brown flakes generally occurs grown together with the amphibole. The p l a g i o c l a s e is often zonary built, with the outer edge containing 20 % An. The main part of the mineral is about an oligoclase.

C a n a l M u r r a y **(45)**. The channel between Peninsula Dumas and Isla Navarino is one of the parts of the Fuegian archipelago most visited by scientific expeditions. Particularly HYADES has described in detail several rock-types occurring here, and the petrography of the locality can therefore be regarded as comparatively well known. As in the older descriptions in general, which have been compiled before the tracts were mapped, it is unfortunately difficult to locate the position of the rock-types described, and by their aid obtain a clear idea about the geological structure.

HYADES (32, p. 128—130) described from Canal Murray »sandstone-schists», quartzite and andesitic tuffs. Of importance is the find of fossil-remains in the sandstone-schists regarded by HYADES as *Textularia* and *Climacamnia*. The determination is, however, very uncertain, and allows of no definite conclusions about the age of the formation, but they might according to the same author be C a r b o n or P e r m.

The channel is morphologically a cross-valley, running almost at right angles to the axial-direction of the sediments. The mountains of both coasts are rather low, of the same shape as in the eastern part of the archipelago in general. They rise abruptly from the narrow strand-flat up to about 300 m. At this altitude the mountains are almost plateau-shaped. On Peninsula Dumas, 10 km or so from the coast, the mountain-crests already rise to more than 1000 m; on the opposite side, on Isla Navarino, they remain at the altitude of 3—400 m for several miles eastward from the coast (*cfr.* Fig. 55, p. XXIV).

The author made only one landing at the narrowest part of the channel, just before reaching the small island Button. Seen from the ship, the general composition of the rock-ground along the coast of the channel seems to be about the following, reckoned from north to south:

At the north end the sediments evidently are of the same rather coarse graywacke (sandstone-schist of HYADES?), which has been described (p. 102) from the south shore of Peninsula Ushuaia. It is slightly folded and almost unaltered. Sometimes the layers occupy an almost horizontal position.

Southward the intensity of the folding gradually increases, and the layers take a more or less vertical position. In the narrows of the channel very beautiful profiles, showing the folding-style, are visible in the steep coast-cliffs (Fig. 51). The folds are usually very steep, slightly thrust towards the

Fig. 51. Folded sediments of the Yahgan-formation at Canal Murray. The folding is drawn somewhat schematically. Looking eastward. Photo E. H. K.

north. The direction of the deformation has been about south to north. The folding axis strikes about east-west and seems to dip slightly towards the east.

The sediments retain their steep position also farther south along the coast of Navarino and the intensity of folding increases in that direction for at least ten km southward.

North of the narrows there are thick layers of white quartzite (or quartz-porphyry?) visible in the shore-cliffs. They are, however, not very important and seem only to constitute interformational layers between the dark schists.

At the narrows (the landing-place) the rock-ground broadly speaking consists of a well stratified series of graywacke and phyllite, with sparse carbonaceous layers. Between the sediments there are often layers of greenstone of a metre thickness. At least some of the layers of graywacke are pyroclastic, as already HYADES has pointed out, and contain microscopic inclusions of a basaltic, usually glassy lava-rock.

The sediments are rather schistose, more particularly the phyllites have a perfect cleavage, though this is already less conspicuous than in the sediments farther west on Peninsula Dumas.

Besides the greenstone interbedded in the sedimentary layers, there are also dike rocks of younger age, crossing the direction of the schistosity. They are of the same character as the dike described above from Bahia Samsing on the north coast.

The petrographically most interesting rocktypes at this place are the following:

Sp. 58. *Graywacke*, Murray narrows, Peninsula Dumas.

The rock is megascopically light bluish-gray and fine-grained. The structure is rather strongly mylonitic but shows very little recrystallization, and shear. The composition is mainly quartz and plagioclase, together with calcite and sericite. The quartz occupies probably less than 50 % of the rock. The components form a very fine-grained matrix in which the different minerals are difficult to distinguish.

This rock-type is the most widespread at the locality visited.

Sp. 53. *Marl-sandstone* (pyroclastic). Murray narrows.

The rock is rather coarse-grained, with calcite as the main component. The mineral forms the matrix in which the other constituents are included. These are mainly small grains of quartz, plagioclase and fragments of a volcanic rock with ophitic structure. The degree of deformation is considerable. The quartz-grains are often rolled out and the carbonatic ground-mass is crossed by shear-zones which bend in lense-form around the more resistant inclusions.

Sp. 56. *Greenstone*. Layer between sediments. Murray narrows.

The rock recalls megascopically in some degree the ophiolitic greenstones of Monte Olivia, but is of a different mineralogical composition. The mineral constituents are light-greenish amphibole, zoisite, chlorite and leucoxene. Occasionally there are dull remains of bigger crystals, probably pyroxene, which are altered to amphibole. The a m p h i b o l e occurs as needle-like crystals occupying more than 70 % of the rock. $\gamma : c = c.\ 20°$. It evidently is a lime-rich variety. The z o i s i t e is colourless with very low anormal bi-refraction and ultra blue interference colours. No plagioclase is visible. Evidently the minerals of the present stage are all secondary and originated through alteration of a plagioclase- and augite-bearing rock which has altered to a tremolite-chlorite-zoisite rock.

Sp. 58. *Lamprophyre*. Dike cutting the sediments. Murray narrows (Microphotograph Fig. 6, Pl. XXVIII).

The rock is megascopically fine-grained, blackish-gray. It consists of a hyalopilitic ground-mass and idiomorphic phenocrysts of hornblende augite and further a white isotropic mineral evidently analcite; in smaller quantities also quartz, magnetite and pyrite.

The mineralogical composition consequently diverges in some degree from the earlier described dike-rocks, which as a rule do not contain augite. The quartz-grains are strongly resorbed and have crystallized at a very early stage of the cooling. This is also the case with the augite crystals. The hornblende is formed rather late and has therefore sharp edges, of the same typical form as in the dikes already described.

The h o r n b l e n d e is always zonar-built, with a darker greenish-brown, pleochroitic kernel and lighter coloured outer part. In the kernel the optical orientation is $\gamma : c = 15.5°$, in the outer part 18.5°. The a u g i t e is colourless to light yellowish-green. $2\ E = c.\ 45°$, $\gamma : c = 50°$. The white isotropic phenocrysts appear under the microscope as rather irregularly formed late chilled grains without sharp edges. They generally show a weak bluish anormal bi-refraction ($n = 1.485$). They might consist of a n a l c i t e.

This rock evidently represents a rapidly cooled dike-rock of about the same composition as the dike described from the north coast of Peninsula Dumas (Bahia Samsing) (*cfr.* also p. 176).

Isla Navarino.

As already has been pointed out, the topographical character of Isla Navarino diverges greatly from that of the other big islands of the southern archipelago of Tierra del Fuego, and has only partly — along the north coast — cordillera-character. This depends mainly upon tectonical conditions. The sediments are decidedly less folded and altered than in the main cordillera-zone, and they have rarely suffered any mechanical deformation strong enough to render it difficult to identify the primary feature of the rocks. However, this does not mean that the rocks are only slightly folded, but rather that they were folded at a high niveau of the earth crust, and during slight stress.

The cordillera-character of the ridge along the north coast of the island (Montes Codrington) is due to the sediments here being tectonically more affected and probably in some degree thrust over the slightly folded sediments along the south coast of Canal Beagle (*cfr.* the stereogram p. 209).

Moreover, with a few exceptions the mountains of Navarino are of plateau-character, this being particularly conspicuous on the east coast and at Canal Murray (Fig. 55), where the mountains form an even high-plateau 300—400 m above the sea-level. The plateau-altitude appears to be somewhat higher on the east coast than on the west, and it is not absolutely certain if they really represent the same plane. The high-plateau of the east coast of Navarino corresponds to the plateau on the north coast of Canal Beagle, E of Puerto Harberton.

From the mountains on the east and north coasts the land gradually slopes to the S and W; the south part of the island is a lowland with rounded hills. Only in the south-west-corner are there some higher mountains (Cerro Brock) reaching about 700 m above the sea. These form the southern end of a long row of mountains, crossing the island in about N-S-erly direction up to the mountains of the north coast.

On the west coast a couple of higher mountains rise over the general height of the coast. These are Cerro Douglas (about 826 m), and Cerro King Scott, which is only 584 m in height, but is remarkable on account of its isolated position and peculiar conical form.

The topographical main-features of Isla Navarino are:

1. The Alpine cordillera-crests along the north coast.
2. The plateau-mountains traversed by several broad valleys.
3. The flats on the south part of the island.

The isolated rounded summits on the east coast which rise over the plateau-level can be regarded as a fourth element.

The rock-ground of the West Coast.

On the west coast the author made no investigations before arriving at Puerto Douglas. The French expedition, however, have provided data also from several points between this place and the Murray narrows.

At the inlet to Murray narrows from the south HYADES describes andesitic tuffs from Isla Pauvre, evidently of the same pyroclastic rocks which the author found, and quartz-rich slate (*Schiste argilo-quartzeux*). On the small island outside Bahia Wulaya there was found an altered fine-grained volcanic rock of basic composition (*labradorite*). It contains labradore-crystals in an amorphic ground-mass, together with a little pyroxene. The present author made a short landing at Estancia Wualya, but had no opportunity to visit the place described by HYADES. The gravel on the shore consists, however, almost exclusively of slaty rocks of the same type as at Murray narrows and it is probable that the basic rocks occur only subordinated.

From the old mission station of Puerto Douglas **(46)** the author made a traverse about 15 km from the coast in north-easterly direction, along the valley of Rio Douglas.

In the surroundings of the station, at the outlet of the river, big boulders of a volcanic breccia deriving from the mountains south of the valley are found (Cerro Douglas). The mountain consists mainly of volcanic rocks with a brownish weathering, and with a very conspicuous vertical jointing in an almost north-southerly direction. The rock is an andesite, which was highly brecciated at the eruption, but otherwise shows no trace of later mechanical deformations.

The only trace of later movements is a brecciation resembling that of the porphyries of Seno Almirantazgo, appearing as open joints in the rock, mainly trending 350°, dipping 75° E and 300°, dipping 90°.

On the point south-west of the outlet of Rio Douglas is found a rather coarse graywacke of pyroclastic character. Also the point north of the outlet seems to consist of sediments dipping steeply north.

East of Estancia Douglas outcropping bedrock was first found in the valley behind the small lagoon which continues the bay of Puerto Douglas. In this locality there occurs a dark-gray carbonaceous, fine-banded slate, resembling the sediments of Canal Murray, but considerably less altered. The strike is about east-west, the dip about 30° S. The pitch indicates an easterly dip of the axial-direction.

On the westside of the broad upper part of the Rio Douglas-valley (Fig. 54), there occurs in a couple of small hills a light-coloured, extremely fine-grained,

layered siliceous rock, with irregular, splitty jointing. It has evidently in some degree been burnt by contact influence, possibly of a lava-rock. The layers strike E-W, the dip is steep (80—85° S).

At the north end of the same valley the surrounding hills consist of even-grained, light-gray granodiorite, a typical Andean diorite of rather acidic composition (*cfr.* p. 175). The same rock occurs probably also in the ridge along the east side of the valley. The latter of these observations shows that the inner parts of Isla Navarino do not consist exclusively of sediments, as indicated on earlier maps, but that there are also extensive areas of dioritic or granitic rocks belonging to the Andean diorites.

South-east of the valley, the effusive rocks of Cerro Douglas are continued eastward to the mountains north of Bahia Grandi on the south coast.

Microscopic description of rock-specimens from the vicinity of Bahia Douglas.

Sp. 63. *Andesite-lava*, Western slope of Cerro Douglas on the west coast of Isla Navarino.

The rock is dark-gray porphyric, with abundant phenocrysts up to 1 mm in diameter, consisting of plagioclase and augite. The ground-mass is partly glassy. It contains amygdules filled with chalcedony in the outer parts, crystallized quartz in the inner. This quartz often includes big cubic pyrite-crystals. The plagioclase is very basic with 62—65 % An. The augite is light-yellowish, almost without pleochroism, and always very strongly resorbed. $2\ E = 38—40°$.

Sp. 60. *Andesite* from boulder on the shore of Bahia Douglas.

The rock megascopically resembles the foregoing, but is more dense. The ground-mass is partly glassy. The phenocrysts consist of plagioclase and basaltic hornblende. The structure receives its typical aspect through the presence in the glassy matrix of phenocrysts of two generations, particularly plagioclase, of which the one consists of sparsely occurring very big crystals, the other of very densely scattered, small, sharply euhedral grains. The big crystals are slightly resorbed. They are always highly zonar usually recurrent. The innermost part is vitreous, possibly depending on a secondary melting of the lime-rich parts during the eruption. The refraction is $n\ \beta = 1.568 \mp 0.005$. The optical properties give the composition 45—80 % An. The kernel is in other words an anorthite. The small phenocrysts are sharply euhedral. The composition is generally more acidic, with 34 % An in the inner parts, 28 % An in the outer part of the grain. The dark minerals play a far less important rôle in the rock. The hornblende crystals are generally small and highly resorbed, often only a dark oxidic pigment remains, which is also often contained in unresorbed grains. The crystals are rather short-prismatic, measuring up to $^1/_2$ cm in length. $\gamma : c = c.\ 6°$. The absorption is γ (dark-brown) $> \beta$ (brown) $> \alpha$ (yellowish-brown), $n_\alpha = 1.680$, $n_\beta = 1.688$.

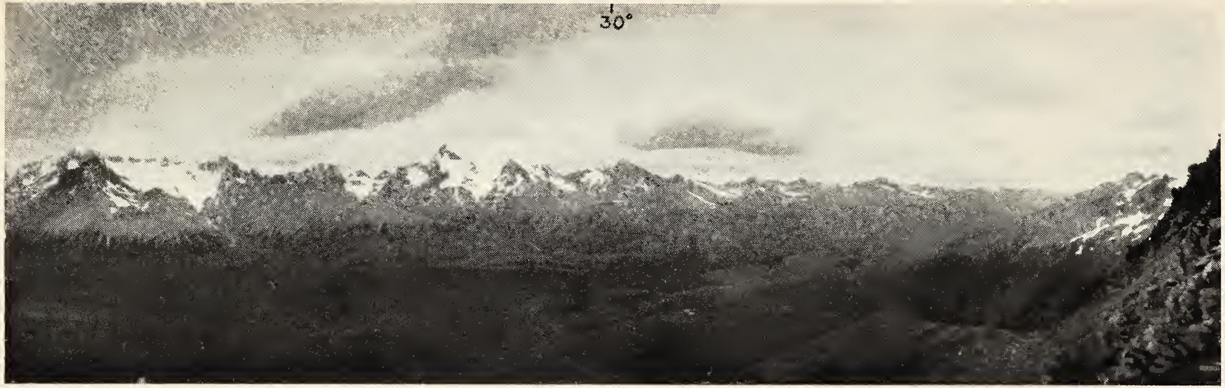


Fig. 52. Valle Carabajal. Looking eastward from the mountain at the junction with Valle Olivia. On the opposite side rises the Alvear-Cordillera. The watershed in the valley is situated below the compass-reading.
Photo. E. H. K.

Fig. 53. View eastward from the mountains N of Monte Olivia. In the centre the summits Monte Cinco Hermanos. The mountains consist of dark slates of the Yahgan-formation.
Photo. E. H. K.

Fig. 54. The valley of Rio Douglas. Central parts of Isla Navarino.
Photo E. H. K.

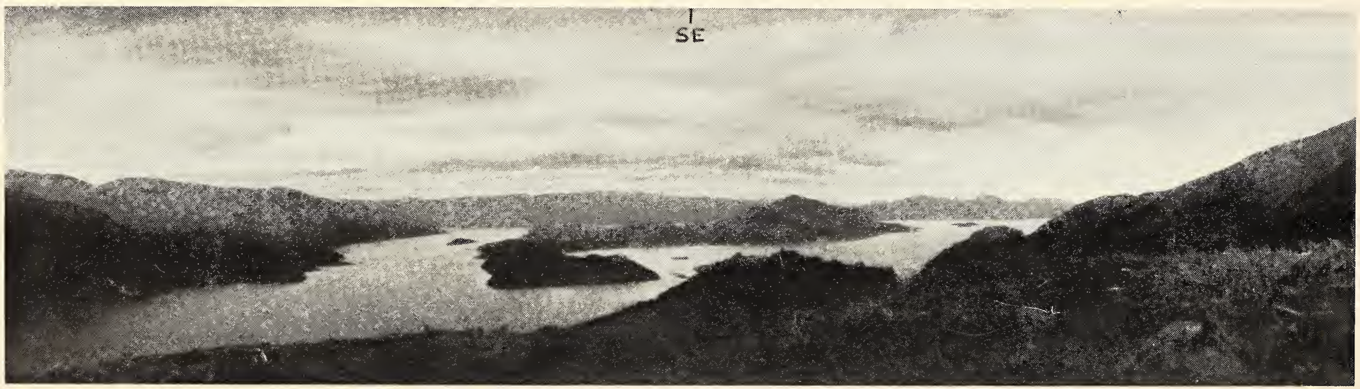


Fig. 55. The west coast of Isla Navarino seen from Murray Narrows. The plateau-like crest of the mountains is clearly visible.
Photo E. H. K.

The sediments of Puerto Douglas seem all to be more or less of tuffitic origin. They are of very great interest because they contain remains of fossils in abundance. The light-coloured, dense rocks named in the foregoing consist mainly of chalcedony with interstratified more coarse-grained, sandstone-like layers. They have generally the same character as the phtanites from the northern parts of the Cordillera described in the foregoing. The black schists are very rich in carbon and an oxidic pigment and often rich in remains of radiolarias, resembling those earlier described. They grade into pure radiolarites. These rocks will further be treated in another connection (p. 149).

The coarse-grained graywacke south of the outlet of Rio Douglas is particularly interesting as it contains microfossils of a slightly different type.

Sp. 65. *Fossil-bearing graywacke.* About $^1/_2$ km south of the outlet of Rio Douglas. Isla Navarino (Microphotographs 2, 3 and 4, Pl. XXV).

The rock is dark greenish-gray. It shows almost no trace of mechanic alteration. Under the microscope it was found to consist of fragments of crystals, volcanic lava and glass, in a fine ground-mass for the most part consisting of chalcedony, calcite and a pigment of ironoxide and carbon. Besides there are needles of a colourless mineral identic with the pseudo-sillimannite of De Lapparent (37). The bigger plagioclase crystals have a composition of about 30 % An. In the glassy lava-fragments there is also plagioclase with a more basic composition (50 % An). The plagioclase is consequently generally the same as in the andesite of Cerro Douglas and there is scarcely any doubt that they belong to the same formation.

In this rock there is an abundance of remnants of radiolarias with a comparatively well preserved shell, shown on the microphotographs Figs. 3 and 4, Pl. XXV. They are of a more developed type than the radiolarias found in the phtanites described from the tracts of Ushuaia and the frontal part of the Central-Cordillera (*cfr.* also p. 149).

The South Coast of Isla Navarino.

The south coast of Isla Navarino is to a great extent covered by thick moraine-deposits. The bedrock is visible on the coast only in the south-western corner of the island, inside Isla Bertrand (Bahia Grandi **47**).

Here the rock-ground consists of plutonic rocks, which the author had an opportunity to study at the outlet of the small river flowing to the west corner of the bay (Rio Grandi). The rocks are strongly differentiated, being partly coarse-grained, partly rather fine. The composition varies in a very high degree within a small area, and is partly a very basic gabbro, partly a leucocratic rock of monzonitic composition. It has often a brecciated aspect, with dark basic inclusions in light-coloured monzonite or diorite. This breccia is of another type than the volcanic breccia described from Bahia Fleurais and other localities within the area of the Andean diorites. The inclusions do not consist of coarse-grained gabbro or hornblendite, but are a fine-grained rock, often with banded structure, which leads to the assumption that they might possibly be included fragments of a sediment. As will be seen in the following,

there are several microscopic features which support such an interpretation (Fig. 3, Pl. XXIX and Fig. 1, Pl. XXX; *cfr.* p. 174).

Near the crest of the high mountains east of the valley of Rio Grandi (Monte Brock) there are layer-like banks darkish-brown in colour, probably consisting of andesite or basalt.

On Isla Bertrand there occur both dioritic rocks and sediments. HYADES (32) reports from here quartz-felspar schist, possibly a contact-metamorphic slate. According to HYADES, the small island Scott, south of Isla Bertrand, is of effusive origin, and consists of andesite. The rock occurs as thick banks, dipping towards the north.

The boulders in the moraine of the south coast consist for the most part of rocks occurring on Isla Navarino and the neighbouring islands. The effusive rocks are remarkably abundant. The principal types are: 1. rocks belonging to the Andean diorite series, ranging from granitic and granodioritic rocks to gabbro and hornblendite; 2. black phyllitic sediments and siliceous schists; 3. basaltic and andesitic rocks, partly porphyrites with big phenocrysts of plagioclase, augite and hornblende.

The East coast of Isla Navarino.

From Punta Guanacho for about 20 km northward the coast is a low *barranca* without cliffs. Then follows a mountaincoast covered with dense wood.

At Puerto Toro **(48)** the cliffs consist of rust-coloured stratified sediments with splitty jointing. The layers generally have an almost vertical position. In spite of the strong folding the sediments are only slightly altered. The lithological composition varies from very quartz-rich dense schists to clayish sediments. Also lime-rich layers have been observed. The firstnamed are for the most part dark, cherty radiolaritic phtanites, which frequently alternate with coarser rocks of pyroclastic origin. They have the character of graywacke. Lime-concretion is abundantly present.

The rock-complex obviously is of the same origin as that on the west part of Isla Navarino at Canal Murray, though less altered.

The strike is generally E-W; the dip is 75°—90° N or S. The direction of the folding axes seems to be about 70°—80°.

The same brownish sediments continue along the coast northward up to the north-east point, but the folding becomes less intensive northwards, in the same way as on the west coast at Canal Murray, as far as can be judged from the sea.

The petrological character of the rocks of Puerto Toro is mainly identical

with that of the rocks described from Rio Douglas. The following specimens can be regarded as representing the average types.

Sp. 87. *Phtanitic schist.* Puerto Toro, E Isla Navarino (Microphotograph Fig. 1, Pl. XXV).

The rock is dark-gray and consists of very dense, cherty layers, interbedded with more light-coloured lime-rich strata. It is megascopically strongly folded and crossed by miniature slopes. The composition is quartz to chalcedony, calcite, epidote, zoisite and pyrite in abundance. In the phtanitic layers the dense ground-mass mainly consists of chalcedony in which remnants of radiolarias are embedded. They generally are of the same simple type which we have described from the tracts of Ushuaia. The fossils are filled up mainly with chalcedony, sometimes also with epidote and ironoxide, the latter as a fine pigment.

Sp. 93. *Graywacke*, Puerto Toro, E Isla Navarino.

The rock is medium-grained, grayish-green in colour. Under the microscope it appears to consist of crystal-fragments, mostly of plagioclase and augite, but also quartz in a fine carbon-rich matrix, for the most part consisting of chalcedony. Also fragments of andesitic and basaltic lavas are frequently seen. The plagioclase-crystals have the composition 28 % An. The femic components are generally very subordinated. The rock resembles the graywacke described from Puerto Douglas on the west coast of the Island, but is here not fossiliferous.

The sediments of Puerto Toro are often slightly carbonatic, but never pure limestones. The comparatively rare occurrence of limestones among the sediments of the Yaghan-formation is a feature which holds good for the whole of the Central-Cordillera of Tierra del Fuego. Nowhere has there been found limestone-areas of importance, or any formation containing lime in greater quantities, though this stuff is found sparsely in several of the sediments. More lime-rich sediments are first found in the Marginal-Cordillera, among the Cretaceous »Flüsch»-sediments.

The North Coast of Isla Navarino.

The north coast of Isla Navarino is known mainly from the few landings made by LOVISATO. The specimens collected at these landings are described by HYADES (32, p. 213—215). A factor of great importance is the discovery of dioritic rocks on the north coast together with schists which, according to the description, are of contactmetamorphic origin with garnet and andalusite (*Schistes a andalousite, éclogite, schiste amphibolique*). The lastnamed derive from the north end of Canal Murray.

The present author had the opportunity to confirm the accuracy of these observations. The dioritic rocks occur from the north-west end of the island eastward to about 8 km east of Ushuaia (*cfr.* the map). This part of the coast is comparatively even and low. A closer examination of the rock was made at Estancia Santa Rosa **(49)**. The rock is here a rather basic typical Andean diorite. The more basic varieties are characterized by dense-

lying black, idiomorphic hornblende crystals, which form the only dark component of the rock (Fig. 4, Pl. XXII). Only the lighter coloured varieties contain also some biotite. The contact between the diorite and the sedimentary rocks occurring farther east, is well visible from the sea, direct west of Punta Peninsula. The sediments are contorted and evidently highly altered, owing to contact-influence due to the intruding diorite.

In the bay, north of P i c e N a v a r i n o **(50)** there occurs a coarse grayish green graywacke of mainly pyroclastic origin, extremely reminiscent of a similar rock-type described from Puerto Toro (p. 134). It is also here interbedded with more fine-grained phyllitic material. The layers strike 70°, dipping 43° S. The folding axis is about east-south-east. The rock is very little altered.

The same kind of sediments compose the slope higher up the mountains and, to judge from the loose boulders, they also form the crests around Pice Navarino. Farther east there was observed black carbon-rich slate at P u e r t o E u g e n i a **(51)**. G. Andersson (2) during the Swedish Antarctic expedition 1898 found a sandstone-schist on Isla Gable in the east part of Canal Beagle. It was evidently a slightly altered graywacke similar to those occurring along the north coast of Isla Navarino.

All the observations quoted above indicate that along the east part of Canal Beagle there is a zone where the sediments are less folded and altered than on the north coast of the channel, and also in the high mountain-ridge south of the coastline (Montes Codrington).

The folding-axis of the sediments strikes ESE, about parallel with the coast-line. The slight divergence was observed already by Darwin. With the exception of a few undulations the axis is very even between Puerto Elenita and Pice Navarino.

The petrographic character of the sediments on the north coast is the same as that of those described from the eastern parts of the island, though they are still less deformed. They do not offer anything of special interest. The diorites are described on p. 169.

Summary of the Geology of the Southern Parts of Isla Hoste and Islas Wollaston.

Through the investigations of the French expedition, and also the Swedish expedition of Otto Nordenskjöld, the coasts of the south-eastern parts of Isla Hoste are amongst the best known of Tierra del Fuego. Only the south-west part of the big island, Peninsula Cloué, is still unknown from a geological point of view.

The most detailed description we have is that from the region of Orange bay on the east coast of Peninsula Hardy, where the French expedition had its winter-quarters. The rock-ground in this region consists for the most part of typical Andean diorites; this name is here used in a very wide sense and consequently also includes related granitic and gabbroidic rocks. There are, however, also a great number of effusive rocks and corresponding tuffs (andesites, diabases, basalts). They have been characterized as prophylites by HYADES (32) and later also by QUENSEL (45). These effusives are of a great extent in the tracts of O r a n g e b a y on I s l a P a c k s a d d l e and the neighbouring part of the coast of Peninsula Hardy (*cfr.* the map). Basalts with very beautiful pillar-jointing are found at C a b o W e b l e y and on I s l a G r a n d e on the north coast.

Also on the I s l a s W o l l a s t o n, which generally consist of Andean dioritic rocks, effusives of the prophylitic types occur on I s l a G r e v y and I s l a F r e u c i n e t. More detailed investigations will probably show that these effusives are of a still greater extent in the Andean diorite area.

For a more detailed description of the igneous rocks of these regions, the reader is referred to the oft quoted work of HYADES (32).

Travelling northwards from Cape Horn sedimentary rocks are first found at B a h i a T e k e n i k a on the east coast of Isla Hoste. The sediments are here partly black carbon-rich slate, partly a rather coarse graywacke, greatly resembling the »Flüsch»-sediments of the Marginal-Cordillera on the north side of the mountain-range. Judging from the specimens obtained by HALLE, which the author has had the opportunity to study, the degree of metamorphosis does not seem to be much greater than in the last-named localities.

On the southern side of Bahia Tekenika these sediments are of a special interest, because they represent the only place in the southern part of the Cordillera where determinable fossils have been found. They are partly plant-fossils and partly molluscs of several kinds; the latter are unfortunately not yet determined. The plants have been determined by HALLE (30) as *Sphenopterys hymenophylloides* and *Dictyozamites cf. falcatus* and *coniferous* fragments. HALLE regarded these fossils as being Middle Jurassic, or at any rate Jurassic (*cfr.* p. 205).

Along the coast north of Bahia Tekenika there occur sediments of the same character as on Isla Navarino. They become more altered farther northward and contain more greenstone of the altered type described from the northern parts of Isla Hoste.

D. FIELD OBSERVATIONS IN THE WESTERN PARTS OF THE PACIFIC REGION.

Canal Cockburn, Paso Adelaide and the Islands south of Peninsula Brecknock.

As already Darwin (17), Hyades (32), O. Nordenskjöld (41) and Quensel (45) have proved, the outermost *i.e.* the westernmost and southernmost parts of the Cordillera of Tierra del Fuego consist of dioritic and granitic rocks, the so-called Andean diorites (Stelzner), without any signs of sediments.

Besides the landings at the localities on the boundary with the sedimentary rocks of the mountain-range, which have been described above, the author made various other landings within this region.

Isla Duntze (52).

Isla Duntze or Islas Duntze, as they are called on the charts, is situated on the north side of Canal Cockburn near the south coast of Isla Clarence. On the chart there are marked two different islands, separated by a small channel. As a matter of fact, as the author had the opportunity to ascertain, this channel is only a bay, which is continued by a low valley with a couple of small lakes (Fig. 56). The valley probably crosses the island from north to south, and has been taken for a channel.

The rock-ground consists on the south coast of the island entirely of dioritic and gabbroidic rocks of rather varying composition. On the east part there is a pure gray, medium-grained diorite, sometimes traversed by pink pegmatite veins with potash-felspar.

The western part of the island around the cross-valley consists of more basic magma-rocks, mainly gabbroidic in composition. This magma has been highly differentiated at the time of the intrusion and forms partly eruptive breccias. A banding of coarse- and fine-grained rock is often visible, the latter is generally highly zoisitized. The banding runs mainly E-W.

Though generally without any sign of alteration, the gabbro sometimes in certain strikes shows rather strong mechanical deformation. The rock becomes fine-grained and granulated and the composition also changes (epidotization). This mechanical influence can hardly be explained as being due only to movements in the magma during the crystallization. It seems to indicate that the diorite complex, at least in some degree, also here has

taken part in the orogenic movements. The same observation has already been made at other localities (Isla Clarence, Isla Gordon).

The gabbros and diorites at Isla Duntze are crossed by a great number of basic, lamprophyric dikes with sharp contacts. Also leucocratic, aplitic and pegmatitic dikes abound (*cfr.* also p. 154).

Islas Enderby **(53).**

Two cliff-islands situated south-east of Isla Duntze. The rock-ground consists of similar gabbros as those on the western part of the foregoing island.

Fig. 56. The valley between the two »Islas» Duntze marked as a strait on the charts. Photo E. H. K.

Islas Nelson **(54).**

Two small cliff-islands in the inner part of Canal Brecknock. The rock is an even-gray, rather small-grained diorite (Fig. 1, Pl. XXVII), of very fresh aspect, without the slightest trace of mechanical influence. The composition is very homogenous and shows no differentiation.

Isla Magill **(55).**

The island is situated on the south side of Paso Adelaide. It has earlier been described by Lovisato (32, pp. 196—197) who from Monte Skyring describes amphibole granite, pegmatite and diorite. The author collected on the north-east shore specimens of a coarse-grained granodiorite.

Around Paso Adelaide and the south part of Canal Barbara the islands everywhere consist of similar granito-dioritic rocks, which extend to the region of Seno Icy on Isla Santa Ines.

Isla Londonderry **(56)**.

The author made a landing on the north-east point of the great island and found Andean dioritic rocks of mainly a rather acidic composition, and quartz-rich granite. They are penetrated by brownish rather weathered dibasic dikes.

The latter evidently are of the same kind as the trachytes observed by LOVISATO on Isla Burnt in Bahia Desolada, W of the entrance of Canal Beagle.

From the last-named island, which is conspicuous on account of the dark brown colour of the rocks found in its upper parts, HYADES describes a great number of different rock-types, which mostly coincide with the rocks belonging to the normal Andean dioritic series.

These are amphibole-granite, quartzdiorite, micropegmatite, augite andesite, diorite-porphyry (granulite), labradorite and augite trachyte. The last-named occurs in the east part of the island.

Other localities visited by LOVISATO on this part of the coast are the South coast of Peninsula Brecknock opposite the island Saint-Paul-de-Londres (quartz diorite) and Isla Basket, S of Peninsula Brecknock (diorite-porphyry with amphibole and amphibole granite which are traversed by porphyritic dikes).

The nature of all these islands along the Pacific coast is more or less the same. They are rather low, rarely more than 2—300 m in height, without any wood-vegetation. They are, however, bare only along the shore and on very steep slopes. The main part of the islands is covered with luxurious peat and moor vegetation. The forms are always rounded and ice sculptured with the proximal sides towards the N. Small cirque formations are very common, and the bays are in many places excavated by ancient glaciers.

The petrological character of the Andean diorites in the localities visited by the author is given on pp. 161—162.

ISLA SANTA INES. SENO ICY (ICY SOUND). BAHIA SMYTH. **(57)**.

Supercrustal rocks were found on the eastern coast of Isla Santa Ines at Seno Icy and Puerto Dean in the north east corner of the island. They are only small remnants, which it is impossible to connect with the other formations in the Cordillera before the opposite coast of Canal Barbara at Isla Clarence has been investigated. The dominating rocks of the locality are of granitic composition.

On the peninsula between Seno Icy and Puerto Dean the shore-cliffs consist of rather fine-grained, brownish schists, alternating with metamorphic greenstone. The first-named seems to be a strongly altered pelitic sandstone of a type resembling the sediments of Isla Gordon on the south coast of Tierra del Fuego. The strike is generally 315°, the dip is almost vertical.

These supercrustal rocks are penetrated by a coarse-grained granite with big (up to 2 cm) muscovite flakes, while farther from the contact there are chloritized biotite flakes of the same shape. Westward these rocks grade into normal granites and diorites, partly of porphyric character. They belong with certainty to the Andean diorite series. The granites here contain abundant

Fig. 57. The mountains E of Seno Icy on Isla Santa Ines. Photo E. H. K.

basic inclusions, without sharp edges, which under the microscope appear to have an almost diabasic constitution, with ophitic structure. They are reminiscent of similar phenomena described by NORDENSKJÖLD (41) from Puerto Angosto and evidently represent earlier crystallized basic differentiations of the same magma, which afterwards have been partly recrystallized and assimilated. They are characterized by great abundance of epidote.

Both the schists and the granitic rocks are crossed by numerous dikes of basaltic composition. Also one gabbroidic dike was observed, which penetrates the schists, but which is older than the granite. (Sp. 234).

South of Puerto Dean, between this bay and Puerto Smyth, the mountains have a different character, the rock-ground being composed mainly of migmatitic mica-gneisses of a decidedly Archaian type. They are highly contorted

and folded into numerous miniature-folds. The axis runs about 300°, and dips steeply towards the SE. The migmatites have consequently got their present style of folding contemporaneously with the folding of the sedimentary rocks of the locality, and the granitization must be regarded as still younger. At the height of land between the sea-arms there occurs an abundance of an old gabbro intensely traversed by granitic and aplitic veins. Farther north the granitic constituents of the rock-complex gradually increase, and on the north-east coast of Isla Santa Ines the cliffs seem to consist of dioritic and granitic rocks.

The petrological character of the rocks appears from the following descriptions:

The granite of Seno Icy shows no trace of mechanical alteration and evidently belongs to the Andean diorites, though it contains abundant microcline and is more acid than the rocks belonging to this group in general. It will be described more in detail later on (p. 159).

The gneiss on the crest north of Puerto Dean (Sp. 233) has a well developed parallel-striation, which, however, mainly depends on the layered primary structure of an assimilated schist, and cannot exclusively be regarded as an indication of mechanical deformation after the recrystallization. Microscopic examination shows that such deformation after all has also taken place, particularly the quartz-grains being crushed up and granulated.

The rock is composed of abundant quartz, saussuritized plagioclase, microcline, brown biotite, and, as later crystallized components, sericite and chlorite. The structure is almost eugranitic, without significant euhedral forms of the minerals. In other words, the rock appears to have very little in common with the ordinary Andean diorites, and the possibility must be taken into account that it really belongs to a rock-series older than the lastnamed one.

Also the gabbro-rock belonging to the same complex differs from the gabbros described from the Andean diorite areas, resembling mineralogically the gabbro described from Bahia Samsing on Isla Hoste (p. 124).

These rock can be regarded as *uralite gabbro* (Sp. 234). The minerological composition is: uralitic amphibole, basic plagioclase, serpentine, with small quantities of light-yellowish biotite, and small quantities of epidote, magnetite, apatite and titanite. The structure is hypidiomorphic. The amphibole is a light-yellowish, almost colourless actinolite, which evidently forms an alteration product of pyroxene. The boundaries are often rugged and uneven, particularly as regards the plagioclase. $\gamma : c = 18$. The plagioclase has the composition 64 % An.

The sediments of Seno Icy are of alternating phyllitic character and quartzitic composition (Sp. 226). In spite of the altered condition, the rocks still show traces of the original clastic structure, with rounded quartz-grains. Besides, there however also is a strong newcrystallization of biotite, colourless epidote, garnet and tremolite. The lastnamed mineral has crystallized chiefly along shear-planes, in the form of rosette-like aggregates of light-green colour. The absorption is not strong (grass-green to light bluish-green). The epidote and garnet and also the biotite mainly occur in different layers.

All the rocks described above are penetrated by *diabase-dikes* (Sp. 220, 224, 229). They are generally dark-gray, fine-grained or dense ophitic rocks composed chiefly of plagioclase, augite and magnetite, as a secondary mineral, chlorite, calcite, epidote, leucoxene etc. The rocks are usually rather altered, the plagioclase being saussuritized and the augite altered to calcite and chlorite. The plagioclase is zonary-built with the composition 46 % An in the outer zone, 64 % in the kernel. Glassy groundmass was observed in one case.

The diabases show no sign of mechanical alteration, and represent the youngest rocks at this place, and are also younger than the Andean diorites. These dikes are not the only ones of the same group in the region. In the following it will be seen that there also occur effusive lavas belonging to the same magmatic cycle (Islas Carlos).

Islas Carlos (58).

The island group, consisting of three small islands, is situated about in the middle of the Strait of Magallanes, opposite Puerto Gallant. The islands are rather low, only rising to abt. 200 m above the sea. They are covered with very luxurious vegetation, probably due in part to the lime-rich soil.

The rock-ground (at least on the southernmost and eastern islands) consists of volcanic rocks of basaltic composition. They have a very young aspect, and have not to any noteworthy degree suffered by mechanical deformation.

On the southernmost of the islands there occur dark, melaphyric rocks together with tuffs and similar pyroclastic sediments; the last-named dipping rather steeply towards the south. These sediments are possibly older than the diabase. On the west part of the islands there occur diabase with pillar-form jointing in vertical position. On the north shore there are stratified sediments in almost horizontal position.

The whole formation is decidedly younger than the rocks of both sides of Canal Beagle *i. e.* the Central-Cordillera-schists on Peninsula Dumas and the Andean diorites on Isla Santa Ines. It has probably intruded in connection with the folding of the Cretaceous sediments of the Marginal-Cordillera (*cfr.* p. 211) and correspond in that respect to the laccolitic intrusions of South Patagonia.

The melaphyre of Islas Carlos has a rather uncommon character, and is remarkable on account of the very basic composition of the plagioclase.

Sp. 241. *Melaphyre*, Islas Carlos, W Strait of Magallanes (Microphotograph Fig. 5 and 6. Pl. IV).

The rock is megascopically dense, dark-gray. The most conspicuous component is plagioclase in short, broad, idiomorphic crystals with a maximum size of about 1 mm. The mass between the plagioclase consists of carbonate, magnetite, glass (abundant) and small microlitic grains of pyroxene and olivine.

The plagioclase is quite clear and unaltered, rarely it contains small grains of calcite. It is always zonary-built, without recurrence. In connection with the last-named there sometimes is seen a slight saussuritization, in the form of a narrow ring around some of the zones. The composition is, according to the optical data, in the outer part 50—60 % An; the kernel (the greater part of the crystal) has 78 % An ($n > 1.565 > n$, section $\perp$ 001,010, extinction 63° in the inner part, 36° in the outer).

The carbonate-mineral forms radial-built, in some degree unevenly scattered spots. It is obviously crystallized later than the other components; the concentric structure seems to indicate a secondary origin. The mineral, however, never forms a fine pigment scattered over the other components, of the type which is so common in rocks with secondary carbonatization. Magnetite occurs in great abundance, in very small black grains, both in the matrix and also within the plagioclase crystals. Olivine is comparatively rare and forms small, very resorbed grains. The pyroxene occurs as almost needle-like crystals of diminutive size. The light pink colour makes it probable that it is a clino-enstatite or hypersthene. The glassy part of the rock is for the most part clear, but sometimes also devitrified. The colour is remarkably dark, probably due to a high content of iron.

The rock represents an eruption-phase not earlier known from this part of the Cordillera, and it was therefore analyzed in spite of the high content of carbonate. The analysis gave the following result:

Table IV.

1.		2.	3.	
SiO_2	48.06	49.30	Qz.	7.38
TiO_2	1.21	2.16	Or.	6.67
Al_2O_3	17.61	17.31	Ab.	25.15
Fe_2O_3	2.49	3.84	An	31.41
FeO	6.02	5.73	Hy	10.56
MnO	0.11	0.14	$CaCO_3$	4.80
MgO	4.31	5.12	$MgCo_3$	6.24
CaO	9.04	8.67	Mt.	3.71
BaO	0.03	4.05	Il	2.28
Na_2O	2.98	4.05	H_2O	1.22
K_2O	1.13	1.73		99.42
P_2O_5	trace	0.26		
CO_2	5.36	0.16		
H_2O+	1.22			
H_2O-	0.77	2.18 (tot.)		
	100.34	100.65	(II, 5, 4, 3; Hessose)	

1. Melaphyre, Islas Carlos. Strait of Magallanes. Analyst L. Lokka.
2. Essexite, Cerro Cagual. Analyst A. G. Nyblom, Quensel l.c.
3. N:o 1. recalculated.

The composition is in many respects unexpected. The rock is not very rich in calcium, despite its high content of carbonate and the basic composition of the plagioclase. The most anorthite-rich part of the plagioclase-crystals evidently forms only a comparatively small part of the rock. The high percentage of iron is evidently in part contained in the glass. Also in this rock we find that the carbon-dioxide content is so high that a calculation is possible only if most of the CO_2 is reckoned as $MgCO_3$. In such a case we get the approximate normal composition No. 3, table IV. In other cases there will be a great excess of corundum, in the same way as in analysis 1, table III, p. 117. The high content of H_2O ÷ shows that the glass is rich in water.

The young age of the rock leads one to compare it with the young laccolites of South Patagonia which, like the rock here in question, are intruded in connection with the folding of the Cretaceous »Flüsch»-formations. Actually some similarities can be found, as shown by the essexite analysis from Cerro Cagual quoted above (No. 2, Table IV), which, in spite of the higher alkali percentage, has many features in common with the melaphyre from Islas Carlos.

Another type of the Islas Carlos melaphyres is represented by:

Sp. 239 *Porphyre basalt.* Islas Carlos (Microphotograph Fig. 4, Pl. IV).

The rock has a dense, greenish-gray ground-mass, with dark phenocrysts of augite and plagioclase and hornblende (up to $^1/_2$ cm in diameter). The ground-mass is for the most part glassy, with very small fluidally arranged plagioclase crystals. The dark components are to small too allow of any determination.

The phenocrysts: The plagioclase forms sharp idiomorphic crystals which are characterized by the rareness of twinnings. The composition in the inner parts is 83 % An. The augite is light-yellowish, with a slight absorption. $\gamma : c = 53°$, $2 E = c\ 45°$. The dispersion is very strong $v > \varrho$. The grains are always idiomorphic, with resorbed edges. In addition the rock also contains crystals of light-yellowish-green hornblende. It is more resorbed than the augite, and seems consequently to be earlier crystallized, which is a rather uncommon sequence of crystallization in this kind of rocks. It is always surrounded by a dark, almost opaque edge, evidently originated at remelting. $\gamma : c = 15°$. The rock contains inclusions of the quartz bearing clastic (tuffitic?) sediments of the island, which indicates that these are at least in some degree older.

The melaphyric rocks of Islas Carlos resemble in many respects those described from Monte Burney in South Patagonia (QUENSEL, 32).

E. PETROLOGICAL REVIEW OF THE CENTRAL-SCHISTS OF TIERRA DEL FUEGO.

The high-metamorphic schists of the »nappe»-zone are characterized by a well developed shear-structure (and »Durchbewegung») and a conspicuous recrystallization extending to complete disappearance of the original structure. They greatly resemble the old geosynclinal-schists of the Alps (*e. g.* the Casanna-schists).

The type and degree of the metamorphosis of course varies in different sectors of the area, in consequence of variations of temperature and stress, and of the time-relation between crystallization and differential-movement. Broadly speaking, comparatively well defined metamorphic zones can be distinguished in the Cordillera.

In the front-part of the overthrust-region, along its northern border, the schists regularly show a strong mylonitization. The rocks are fine-grained and crushed up, the recrystallization has not in any high degree been able to heal the crush-structures. The shear-movements, which took place at comparatively high level, continued right up to the last stage of new-crystallization in the rock, and they seem partly to have been still younger than the last-named. The principal femic new-formed components are epidote, sericitic mica and chlorite, generally also actinolite, titanite and iron-ore. The salic components are generally albitic plagioclase and quartz — the last-named being the only mineral which with certainty belongs to the primary composition.

In the inner parts of the Cordillera — Fjordo Martinez, Bahia Sarmiento, the innermost parts of Fjordo Finlandia etc. — the mylonitization is still strong, but the recrystallization is more advanced and the new-formed minerals not so highly granulated. The crystallization is, however, completely

---

EXPLANATION TO PLATE XXV.

Fig. 1. Phtanite containing radiolarias. The Yaghan-formation at Puerto Toro. E coast of Isla Navarino. Magn. 46 ×, Nic. ‖.

Fig. 2. Fossil-bearing graywacke (f = fossils) Rio Douglas, W-coast of Isla Navarino. Magn. 60 ×, Nic. ‖.

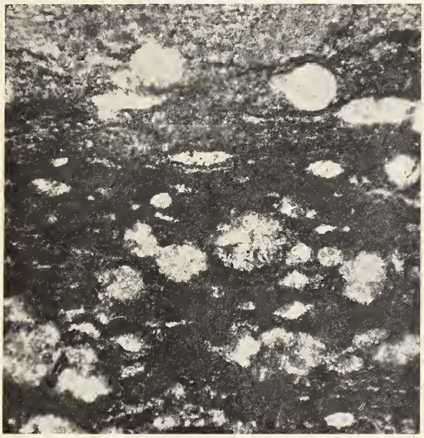
Fig. 3. Detail from the same graywacke as fig. 2. Shell of radiolaria. Magn. 145 ×, Nic. ‖.

Fig. 4. Detail from the same graywacke as fig. 2. Shell of radiolaria and on the right side a flake of Pseudosillimannite (p.) Magn. 145 ×, Nic. ‖.

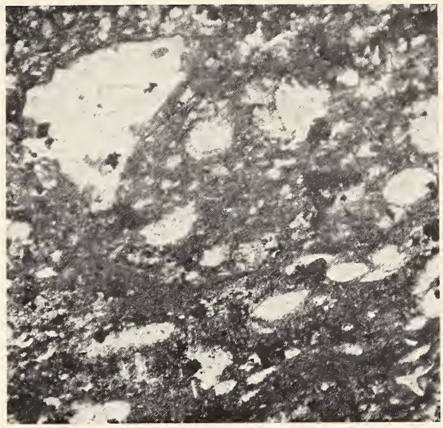
EXPLANATION TO PLATE XXVI.

Fig. 1. Banded schist with well developed transversal schistosity. The dark layers are fossil-bearing phtanites, the light-coloured fossilfree tuffitic layers. About $^1/_2$ natural size. Isla Tres Magotes, Seno Almirantazgo.

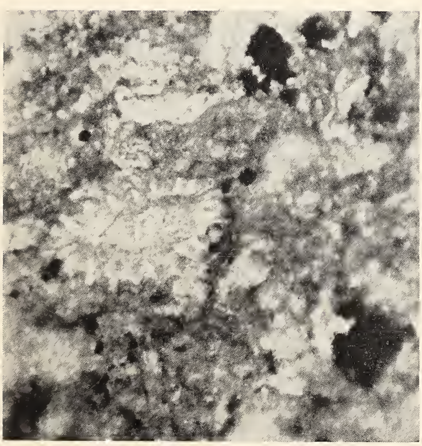
Fig. 2. Radiolaritic phtanite, Puerto Toro, E coast of Isla Navarino.



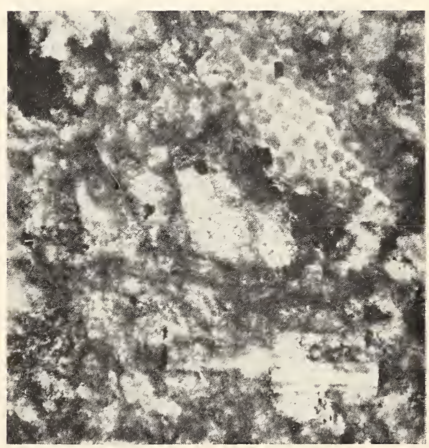
1



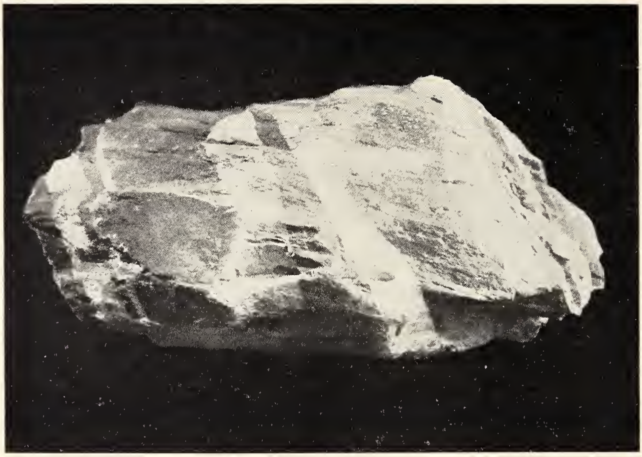
2



3



4



1

2

ruled by the shear-movements. The mineralogical composition is mainly the same as in the foregoing schists. The argillitic and quartzitic schists are altered into sericite-biotite schists and sericite quartzites; the last-named are always strongly granulated and show the typical sugar-grained structure. The greenstones are changed into prasinites with albitic plagioclase.

In these schists a distinct sequence of crystallization can often be observed; the minerals are not formed contemporaneously, but at different stages of the metamorphosis. The mica-minerals are generally, at least in part, of very early origin, most likely the first deformation of the rock; the epidote has also partly been formed early, partly in connection with a later shear-movement; the chlorite frequently is of still later origin. The last-named mineral usually crystallizes also after the finishing of the tectonic influence on the rock, replacing the earlier formed femic components.

In the southernmost sector, comprizing horizons near the rootzones of the overthrust schists, the petrological conditions are more varied (Puerto Olla, Puerto Garibaldi, south end of Fjordo Martinez). The new-crystallization is strong, and decidedly orientated (gerichtet). The quartz-grains are elongated, lenselike, and the seamformed minerals parallel-orientated. Mylonitization is generally absent. The rock has not been to any considerable degree influenced by movement after the consolidation of the main components. In other words, the latter were contemporaneous and coincident with the movements of deformation, which here — according to the mineralogical composition — probably occurred at higher temperature, and also at higher stress than in the outer zones.

Typical mineral components of this zone are garnet and alkaline amphibole and also epidote, mica and chlorite. The rock-types generally occurring are a glassy quartzite with garnet, glaucophane-epidote-garnet schists, mica-garnet schists and prasinitic greenstones, frequently completely zoisitized. The rockground resembles the high-metamorphic inner parts of the Pennine Alps. To the same group belong also the granitized gneissic rocks from the tracts of Puerto Olla and Jendegaia. The paragenesis, epidote, basic plagioclase and bluish hornblende with garnet occurring here, have evidently been caused by the contact-influence of the Cordillera-granite (p. 186).

It is on the whole a remarkable fact that the garnet-bearing parageneses thus are found along the contact-zone with granitic rocks, and there consequently undoubtedly exists a connection between the mineralizations and intrusion of the latter rocks.

In the high-metamorphic schists in the outer zone the sequence of mineralization is still more significant than in the mylonitic schists in the inner sectors.

After the origination of the big idioblastic amphibole and garnet grains, a light deformation, with shear-planes bending around the garnet grains, seems to have been of regular occurrence. Contemporaneously sericite and more particularly epidote and chlorite-minerals have crystallized. During the last stage of the development of the rock, chlorite has replaced the garnet, forming pseudomorphosis of sharp crystal-form, without the slightest influence of mechanical stress. The latest mineralization in the rocks consequently corresponds chemically to the main-paragenesis of the mylonitic schists in the inner and front parts of the overthrust-zones.

The types of metamorphosis within the central parts of the Cordillera of Tierra del Fuego are ruled by the following circumstances.

1. The recrystallization is contemporaneous with, and partly later than the main-stage of movement. (The front of the »nappe»-zone).

2. The recrystallization is coincident with the main-stage of movement.

3. The main-deformation is contemporaneous with, but also partly later than the recrystallization (the strongest mylonitization occurring in the front parts of the »nappes»).

The mineralogical composition of the schists described above corresponds for the most part to the greenschist-series and partly to the glaucophane-schists well known from several descriptions and investigations. They compose the characteristic paragenesis of orogenic zones with »nappé»-movements and strong shear-deformation (Durchbewegung). They fit without difficulty into the classifications of Novarese (43) and of Grubenmann (28) (Alpine schists), and also into the facies-classifications of Vogt (62), Eskola (19) etc. Among newer detailed descriptions dealing with the same kinds of rocks particular mention must be made of the paper by Tschopp (61), dealing with the Casannaschists of Val de Bagne and that by Otto Weg (63) on the prasinitic rocks from Hainischen-Bebersdorf, in which also the chemical reactions and mineralogical development of the rock-types are studied in detail.

If we think of the minerals present, and not of their percentage in the rock, it is impossible to connect the mineralogy of the greenschist- and prasinite-»facies» with the theory of equilibrium, in spite of the very similar mineralogical composition of all rocks belonging to these facies. The investigations quoted above, as well as earlier papers dealing with the rock-types in question, clearly show that the mineralogical composition was not originated within one single phase of metamorphosis, but represents several stages of deformation and recrystallization, partly during fairly varying conditions. The time-intervals between the different stages might in part be very long, and the physico-chemical conditions might undergo a considerable degree of change. Also the

original composition of the rocks has undoubtedly often changed during the deformation, as for instance the investigations of Weg (63) have proved. The origin of the greenschist and glaucophane-schist paranegesis is after all mainly a kinetic problem, in less degree a static one.

The fossiliferous slates of the Yahgan formation and the Buckland series are only slightly altered by recrystallization, though the deformation often is very strong, giving rise to shearing and miniature-folding and also mylonitization in the rocks. In connection with the last-named there is always a new-crystallization of microscopic, indeterminable, generally needle-formed or flaky minerals, often sericitic, but also consisting of talc, actinolite, etc. Quartz and calcite of several generations are frequently deposited along fissures. The degree of deformation is very diverse in different localities of the area and often varies within a small space In places where the movements in the rocks have been strong, the slates are deformed into phyllites with a perfect cleavage along the shear-planes, and with lenseformed, rolled-out, crushed mineral-grains. In most cases the original structure, however, is well preserved, and the microfossils are, if not determinable, generally identifiable.

The fossil-bearing rock-types of the formations are mainly the following:

1. Banded phyllites consisting of light-coloured psammitic strata (Fig. 1, Pl. XXVI) and dark pelitic or argillitic carbon-rich strata. Also lime-rich strata are frequently found. The fine-grained strata are rich in radiolarias, frequently forming the major part of the rock. Frequently there are seen regular varves with coarse stuff in one part of the varve, very fine in the other, with gradual transition (Fig. 2, Pl. IV). The fossils are layered on the boundaries between two varves, often in very thin radiolaritic layers. The fine-structure of the radiolarias is generally destroyed, only the outer form is preserved, forming sharp ovoids filled up with chalcedony, felspar or epidote. Also calcite is sometimes present.

2. Carbon-rich slate, consisting of a dense black, almost opaque ground-mass, in which are embedded radiolarias, generally occurring in abundance.

3. Jaspilitic schists or phtanites consisting of a very dense hard flint-like stuff, usually with a fine banding. They are of great extent, both in the south-east part of Tierra del Fuego and on the north side of the Cordillera. An interesting fact is the intimate association with the quartz-porphyries of the Cordillera. It is very probable that the silica of the cherty

schists, and perhaps also of the radiolarias derives, from quartz-porphyric tuffs. As a matter of fact, tuffitic layers and crystal-fragments are frequently found embedded in the radiolarites.

4. Graywackes. Another type of tuffitic rocks containing fossils are the graywackes of the south-western parts of the country (Isla Navarino, Peninsula Dumas). They consist of crystal-fragments, mostly quartz, basic plagioclase and augite, and fragments of a basic, often glassy, lava-rock of basaltic to andesitic composition. The matrix is partly siliceous, partly carbonaceous. Quartz-porphyric fragments are never found. The fossils in this horizon are radiolarias and globigerinas (?) of an aspect slightly different to those mentioned above (*cfr.* p. 133).

The alteration in the fossiliferous schists is generally less conspicuous. In the phtanitic schists there is generally a very fine pigment with high bi-refraction in the more deformed parts. It evidently consists of sericite, which here consequently is the first mineral to originate at the orogenic movements. Epidote and chlorite are generally present in the lime- and magnesia-rich varieties.

Of great interest is the occurrence in the less deformed varieties of a colourless prismatic mineral with rather high refraction and bi-refraction. It is optically positive in the main-zone, and usually several prismas occur clustered together in more or less parallel positions. There is often a small spot of carbon in the ends of the crystals. The mineral corresponds in every respect to the *pseudo-sillimannite* described by De Lapparent from Devonic phtanitic schists from Valée de la Bruche (39). Prof. De Lapparent was kind enough to send a sample of the rock described by him for comparison, and he himself stated on the occasion of a visit that the mineral from the two occurrences was identical. A fact of great interest is that this mineral in both cases occurs in connection with similar fossils in the same type of sediments, which seems to point to exactly similar conditions of origin (*cfr.* also p. 133).

V. THE ANDEAN DIORITES OF TIERRA DEL FUEGO.

A. LOCAL DESCRIPTIONS.

General remarks.

The supreme importance of the rock-group named above seems to be sufficient reason for a special treatment of the Andean-diorite-series, which, in spite of the numerous descriptions published by different authors, since Stelzner introduced the name, is still but incompletely known. In the following the different rock-types and their geological position in the mountain-range will be investigated.

The extent of the Andean diorite area has been defined by the investigations of Hyades, Nordenskjöld and Quensel in especial (32, 41, 45). Nordenskjöld has pointed out the similarity of the Andean diorites of the Magallanes-territories and the corresponding rocks in the northern parts of the South-American Cordillera, and has parallelized similar rocks also from North-America up to Alaska. He presumed that there have been, during the same time, dioritic intrusions along the whole Cordillera range. Quensel has particularly determined the extension of the South Chilenean diorite-batholith and was able to follow similar rocks from Tierra del Fuego up to Puerto Montt.

The investigations by the present author have not given many new data about the distribution of the Andean diorites in the Magallanes Territories (*cfr.* the map). Only on Isla Navarino has he found that the rocks in question are more widespread in the inner parts of the island than earlier was known.

At a cursory survey in the field the general aspect of the Andean diorites is without doubt very monotonous, in spite of the varying chemical composition of the rock-types referred to this rock-group, and the numerous local variations, which in almost every locality may be observed on more thorough investigation.

All over the whole tremendous area of lone mountainous islands and cliff-coasts the rock-ground consists of the same light-gray, medium-grained rock, occasionally alternating with darker-coloured rocks, representing the basic varieties of the same series. The boundaries between the different varieties are rarely sharp, unless they form eruptive breccias with each other in the way already described. Dike rocks, especially dark basic dikes, are of frequent occurrence. In contrast herewith, pegmatites are almost entirely absent in the typical Andean diorites, which indicates a more hyp-abyssal than really deepseated character of the rock-mass.

The petrographic character of the Andean diorites of Tierra del Fuego was for the first time described in detail by HYADES, whose investigations embrace a great number of specimens from the tracts south of Isla Grande de la Tierra del Fuego. NORDENSKJÖLD was the first to give a general review of the Andean diorite-series and to make an attempt to settle their position among the dioritic rocks. He proved that they also include comparatively potash-rich varieties, and that particularly the more acid types correspond to the adamellite-monzonite series of BRÖGGER, being transitional forms between the real natron-lime series and the potash-series. Broadly speaking, this classification may hold good, though it is based upon a comparatively small amount of observations, comprising only a few of the existing types.

An exact idea about the petrology and the differentiation of the Andean diorites can be obtained only if also the local distribution of the rock-types and not alone their composition be taken into account. In the following, the localities investigated will therefore be described one by one, in order to demonstrate the variations in the field. Afterwards some general conclusions will be drawn about the intrusion process of the magma.

The Andean diorite area of Tierra del Fuego (*cfr.* the map) may be divided into a westerly section, comprising the outer archipelago from Isla Desolacion to the south part of Isla Hoste, and an easterly one, comprising the Andean diorites north-east of the sector of cordillera-schists, which extends over Isla Gordon and Isla Hoste to Islas Wollaston. The former is a continuous area of very similar igneous rocks, the latter consists of several small areas, which cannot directly be proved to belong to the same igneous body, and which contain more varying rock-types.

The observations are restricted to the region from Isla Santa Ines in the west to Isla Navarino in the east and comprise mainly the northern and north-western parts. We have, however, from the south coast of Isla Hoste the detailed descriptions of HYADES, and from the westernmost part of the archipelago the investigations of NORDENSKJÖLD (from Puerto Angosto and Puerto

Chucurra on Isla Desolacion) and the area therefore can be regarded as being at least fairly well known. The only tracts from which we have no data at all are those south of Isla Gordon, Isla Londonderry and Isla Santa Ines, *i.e.* the open storm-lashed coast of the Pacific Ocean. Some scattered observations of crystalline schists and effusive rocks from islands outside the archipelago, Islas Ildefonso, WEDDELL (11, p. 2—22) and Graves Island, KING (36, p. 7) Islas Evangelistas, QUENSEL (45, p. 17—18) have, however, been interpreted as evidence that the Andean diorite area does not extend far outside the coast.

In the following will be shown that, in spite of local variation, the general character of the rock-ground is so similar that we already on account of the data at hand are entitled to draw some general conclusions about the geology of the great »coast-batholith» of the southernmost Cordillera of South-America. From a geological point of view two questions are particularly important and will be treated in the following:

1. Is there any general change in composition of the rock-ground from one part of the Andean diorite area to another, taken as a whole?
2. Are the local variations of rock-types in every locality mainly the same?

The observations hitherto carried out evidently enable us to answer the first question with fairly great exactitude; whereas, as regards the second question, the exactitude is merely approximate.

The Archipelago South of Canal Cockburn.

In the archipelago around Paso Adelaide and Seno Melville the rock-ground of the coasts consists of gray-coloured dioritic rocks, frequently grading into more dark-coloured basic varieties of gabbroidic composition.

On Isla Magill, earlier described by Lovisato, the dominating rock is a rather coarse-grained quartz-diorite, characterized by big, almost black, short-prismatic crystals of hornblende and white plagioclase. Besides these main components, which occur in almost equal quantities, and form at least 80 % of the rock, subordinated quartz, magnetite, biotite, sericite, apatite and titanite are found. The quartz contains an abundance of small needle-like crystals of microscopic size. They penetrate the boundaries between the quartz-grains and the plagioclase, which also contain similar inclusions, though in smaller quantities. The origination of these peculiar inclusions, which are frequently seen in the Andean diorites, has evidently taken place during a late stage of the crystallization. They are too thin to be determined

under the microscope, although they may be several mm in length, but they may consist of some titanium-mineral, probably rutile or ilmenite.

On Isla Magill also more basic, gabbro-dioritic rock-types have been observed (*cfr.* HYADES, 32).

Also Islas Enderby belong to the same gabbro-dioritic rock-complex. The basic varieties seem to dominate here.

The author found a comparatively great variation of rock-types on Isla Duntze, south of Isla Clarence in Canal Cockburn. The types occuring here seem to be fairly representative of this part of the batholite, and the main types therefore will be described more in detail. The following sample derives from the eastern, more leucocratic part of the island. It was penetrated by pegmatitic veins, consisting of red potash-felspar and quartz.

Sp. 24, 25. *Augite-hornblende-biotite diorite.* East part of Isla Duntze, Canal Cockburn.

The rock is evenly medium-grained, rather dark-gray in colour. The main components are all visible to the naked eye. The mineral constituents are plagioclase, augite, hornblende, biotite, quartz and sparingly epidote, magnetite, titanite, apatite and pyrite.

Sometimes also small quantities of potash-felspar are present, but generally all the potash-amount is contained in the biotite. The structure of the rock is hypidiomorphic-granular. The plagioclase has rather well developed crystal form, and is always strongly zonary-built, with a gradual change of the composition, from the edge to the kernel, without recurrence. The composition is between 27 % and 45 % An. Twinning lamellation is always well developed. The augite, which occurs as slightly resorbed grains, is colourless to very light-yellowish. $\gamma : c = c.\ 42^\circ$, $2\,E = c.\ 72^\circ$. It is evidently rich in diopside. In the kernel of the grain there often is an aggregation of cummingtonite, probably representing alteration products of an early crystallized enstatitic augite. Together with dark-yellowish-brown biotite the pyroxene forms the dominating femic component in some varieties; in other places the augite is partly or entirely replaced by green hornblende. The augite-bearing varieties of the Andean diorites generally contain late-magmatic constituents in less abundance than the more acidic, hornblende-bearing components.

Epidote is generally present, partly as independent, sharply idiomorphic grains, partly as an alteration product of other femic minerals.

The order of crystallization was: (enstatite) → cummingtonite → diopside → hornblende → biotite → epidote.

The quantitative mineralogical composition of the augite diorites of Isla

Duntze shows rather big differences within a small area. The rock-type of the western part of the island described above gave upon geometrical analysis composition 1 in the Table below. Another sample, taken a little more to the west, (not more than $^1/_2$ km) showed composition 2.

	1.	2.
Quartz	9.4	22.7
Plagioclase	56.6	48.0
Biotite	17.9	17.6
Augite	11.9	7.7
Hornblende	1.8	0.9
Magnetite	2.3	2.9
Titanite	0.1	0.1
Epidote	—	0.1
	100.0	100.0

N:o 2 is more leucocratic, but the mineralogical composition is exactly the same in both varieties. As these rock-types seem to be very typical for the Andean diorites Dr. Lokka made a chemical analysis of N:o 1, with the following result (Tab. VII).

TABLE VII.

1.		Norm.		
SiO_2	59.05	Qz.	10.68	
TiO_2	0.96	Or.	10.56	
ZrO_2	0.01	Ab.	31.96	Sal. 76.27
Al_2O_3	16.64	An.	23.07	
CrO	non	Di.	9.25	
Fe_2O_3	2.56	Hy.	8.50	
FeO	4.26	Il.	1.82	Fem. 23.95
MnO	0.10	Ap.	0.67	
MgO	3.31	Mt.	3.71	
CaO	7.23		100.22	
BaO	0.09			
Na_2O	3.78			
K_2O	1.77			
P_2O_5	0.33			
F	n.d.			
H_2O +	0.26			
H_2O —	0.04			
	100.38	II, 4, 2, 2.		

1. Augite-biotite diorite, Isla Duntze, Canal Cockburn. Anal. L. Lokka.

The composition corresponds very closely to that of the augite-hornblende biotite diorites of a similar kind described from the North-American Cordillera, *e.g.* from Clayton Peak in Utah, the diorite-areas of Montana, etc.

From the western part of Isla Duntze, where basic varieties of the Andean dioritic rocks predominate, the following rock-types derive. The first is closely connected with the foregoing, though generally consolidated a little earlier.

Sp. 32. *Olivine-gabbro*. West part of Isla Duntze, Canal Cockburn.

The rock is evenly medium-grained, dark-gray, with the femic components preponderating over the salic. The structure is panallotromorphic, with irregular boundaries between the mineral components. The mineralogical composition is: plagioclase, olivine, biotite, augite and small quantities of light-green hornblende, magnetite, apatite, and sulphides.

The p l a g i o c l a s e forms about 35 % of the rock. It is slightly idiomorphic in respect to most of the other components, including the pyroxene. Zonar structure is almost absent, as in all the Andean diorite varities containing basic plagioclase. According to the extinction the composition is 74 % An. Twinning-lamellations according to the Carlsbad, perthite and pericline laws. The b i o t i t e is comparatively light-coloured, orange-yellow to copper-red. On the contact with olivine there is generally a light greenish-brown reaction rim of hornblende. The o l i v i n e occurs as irregular, strongly resorbed grains, often surrounded by pyroxene. The mineral is sometimes altered into serpentine, and contains inclusions of magnetite. The p y r o x e n e is of another type than in the augite diorites and is a clinoenstatite. The optical properties are the following: α = colourless, β = light-pinkish γ = light rose-reddish. $\gamma : c = 28°$. The bi-refraction is comparatively low. The mineral is often altered to light-green actinolite, occurring more particularly on the boundary between biotite and augite. Between the pyroxene and the magnetite there frequently can be observed a symplectite-like intergrowth of magnetite in pyroxene.

The chemical composition of this rock is shown by the following analysis, carried out by Dr. LOKKA (Table VIII).

The rock is very rich in magnesia, and resembles in that respect several noritic rocks. The content of alumina is also comparatively high, and indicates a very high percentage of felspar. The last-named is rich in anorthite, and the rock is therefore poor in natron.

Besides this olivine-gabbro, also another ultrabasic member of the series without olivine occurs, consisting exclusively of brown basaltic hornblende, plagioclase, magnetite and colourless pyroxene. It has the following petrographical character:

TABLE VIII.

I.		Norm.		
SiO_2	46.69	Or.	3.34	
TiO_2	0.35	Ab.	7.34	
Al_2O_3	18.51	An.	44.20	Sal. 54.88
Fe_2O_3	0.66	Hy.	22.48	
FeO	7.63	Ol.	18.90	
MnO	0.11	Cd.	0.20	Fem. 47.37
MgO	14.85	Mt.	0.93	
CaO	8.94	Il.	0.61	
Na_2O	0.89		98.00	
K_2O	0.52			
P_2O_5	non			
$H_2O +$	0.61			
$H_2O -$	0.09			
	99.85	III, 5, 5; Kadebekase.		

1. Olivine-gabbro, Western part of Isla Duntze, Canal Cockburn. Anal. L. LOKKA.

Sp. 27. *Hornblende-magnetite gabbro.* Isla Duntze. Canal Cockburn.

Megascopically the rock is fine-medium-grained, dark-gray, with elongated black hornblende crystals visible to the naked eye. The structure is panallotriomorphic, with rounded edges between the mineral-components. The sequence of crystallization was 1. augite (only fragments left), 2. plagioclase (the mineral has a tendency to idiomorphic crystal-form), 3. hornblende (partly contemporaneous with the felspar, partly later), 4. magnetite, forming a late-crystallized filling between the other components.

The plagioclase is a bytownite (n > 1.570 > n) of rather homogenous composition, without zonar structure. It is generally clear and unaltered, with twinnings according to the albite and pericline laws, rarely according to the Carlsbad law (the last-named twinning law seems generally to be more common in the acidic varieties in the Andean diorite series). The hornblende is interesting, because it frequently is completely filled up with fine needle-shaped crystals (ilmenite?), orientated in groups, of which some are parallel with 010, some with the axes a and b. The absorption is not very strong: γ (greenish-brown) > β (light-greenish-brown) > α (light-brownish-yellow). $\gamma : c = 13.5°$. The augite occurs only as rounded fragments, embedded in hornblende, which evidently for the most part has grown at the edge of the former. It also contains the same needles, which seem to

be connected with this alteration, and may have originated at a precipitation of the titanium content in the pyroxene, which is not contained in the molecule of the hornblende.

In the augite is also occasionally seen an alteration into light-green actinolitic hornblende, which seems to be older than the origination of the brownish hornblende. The same observation was also made in the foregoing rock-type (Sp. 32). Here the brownish hornblende, however, was only developed in thin »coronas» on the edge of magnetite etc. The m a g n e t i t e is remarkable on account of the great quantities contained in the rock; next to the hornblende it is the most important femic component. Biotite is completely wanting.

The uncommon mineralogical composition of this rock makes the analysis of great interest. This was carried out by Dr. L. Lokka with the following result: (Table IX).

TABLE IX.

I		Norm of I				
SiO_2	38.07	Or.	2.22			
TiO_2	3.62	Ab.	13.90			Sal. 54.76
Al_2O_3	17.17	An.	38.64			
Fe_2O_3	9.07	Di.		6.32	10.96	
FeO	9.10	Wl.		4.64		Fem. 45.79
MnO	0.17	Ol.	Fe.	2.45	14.77	
MgO	8.16		Mg.	12.32		
CaO	11.74	Mt.		13.22		
Na_2O	1.55	Il.		6.84		
K_2O	0.34			100.55		
P_2O_5	trace					
H_2O +	0.76					
H_2O —	0.08					
	99.83	III, 5, 5; Kedabekose.				

1. Hornblende-magnetite gabbro, Isla Duntze, Canal Cockburn. Anal. L. Lokka.

The chemical composition of the rock, and particularly the low silica content, makes it difficult to place among the igneous rock. It most likely belongs to the hornblendites, but differs from most of these rocks through the comparatively high plagioclase-percentage. It can be regarded as a transi-

tional form between gabbro and hornblendite, and represents an extremely strong enrichment of iron in the magma during the later stage of the crystallization.

Together with the rock-types described above, which are especially typical of this locality, and also afford good examples of the more basic parts of the rock-complex, there occur on Isla Duntze also more acid diorites, both quartz-bearing hornblende-diorites and hornblende-diorites very poor in quartz. They generally contain a plagioclase with about 45 % An in the centre. The mineral is, however, always zonally built, with more acid marginal zones (24—28 %). Sometimes the rocks are conspicuously influenced by mechanical stress and movements and then contain large quantities of epidote and zoisite.

Several dike rocks, both such of diabasic composition with ophitic structure, and hornblende porphyries, penetrate the deepseated rocks at this place.

Seno Icy, Isla Santa Ines.

The Andean dioritic rocks here occur on the contact with older sediments and therefore several boundary varieties meet. The normal type is a rather acidic hornblende granodiorite (Sp. 223 and 227) containing abundant quartz and albite-rich plagioclase. The mineralogical composition is: plagioclase, quartz, potash-felspar, hornblende, biotite (partly chloritized), magnetite, epidote, titanite and apatite.

The plagioclase is of zonar-structure, but with a comparatively small difference between the inner and outer zones. The outermost has 24 % An, the innermost part 36 %. The main part of the grain about 33 %. The hornblende is light-green ($\gamma : c = 17°$), the biotite very dark-coloured, with strong absorption from light-yellowish to brownish-black. The potash-felspar is perthitic.

In the same locality there occurs a porphyric medium-grained rock, representing a very typical boundary facies of the Andean diorites, and which has under the name granulite and microgranulite been described by Hyades from several localities along the border of the diorite area. (Isla Packsaddle, Orange Bay, Isla Burnt, Puerto Garibaldi and other places). The rock is megascopically rather light-coloured, with big white plagioclase phenocrysts, and small black hornblende needles embedded in a fine-grained, microdioritic ground-mass. The plagioclase is of the same character as in the foregoing rock.

Another boundary variety is represented by a very coarse-grained acidic granite, occurring along the contact with a quartzite on the north-shore of the bay. It contains big flakes of muscovite up to 2 cm broad, and farther from the contact similar flakes formed of chloritized biotite. Under the microscope the rock has the same youngish, unaltered and undeformed aspect as a normal Andean diorite, with euhedral plagioclase grains and quartz as the dominating components. Perthitic potash-felspar occurs fairly abundantly and the plagioclase is albite-rich and has only a light zonar-structure. Occasionally there are also seen small grains of garnet, indicating that parts of the boundary rock have probably been assimilated.

The dioritic rocks of Seno Icy frequently contain basic inclusions deriving from earlier crystallized diabasic parts of the same magma. They are generally rich in epidote and chlorite. The same type of inclusion has been described by NORDENSKJÖLD (41).

The Islands South of Peninsula Brecknock.

In addition to the data from the tracts south of Brecknock previously furnished by DARWIN and HYADES (Isla Basket, Isla O'Brian) a number of rock-types representing the most important types from Isla Londonderry and Isla Nelson will be given in the following.

Sp. 214. *Hornblende-quartz diorite.* East end of Isla Londonderry.

The rock is gray-coloured, even-medium-grained. The megascopically most emergent mineral components are white plagioclase and black hornblende. The structure is hypidiomorphic, the plagioclase crystals are in part crystallographically well developed. They constitute more than half of the rock, the quartz being far less important. Potash-felspar is absent. The composition is: plagioclase, quartz, hornblende, biotite, magnetite, muscovite (sparsely), epidote, titanite, apatite, and zircon (the four last-named in abundance).

The plagioclase of the rock shows high zonar-structure, but this is less conspicuous on account of the complete absence of recurrence. From the outer parts to the kernel the composition gradually changes. The first-named have 37—38 % An, the latter 42—43 %. The quartz is slightly undulose, and in some degree granulated. It contains in great abundance infinitesimally minute needles of a mineral, which might be some titane-compound, ilmenite or rutile. The hornblende is light-coloured, evidently an actinolitic variety. The absorption is γ (green) $>$ β (yellowish-green) $>$ α (greenish-yellow). $\gamma : c = 12°$. The outermost zone is generally more bluish-green. The mineral occurs as big, comparatively late crystallized crystals, often surrounding groups of idiomorphic plagioclase crystals. The biotite is dark-brown, always with beginning alteration into chlorite and muscovite; the latter generally occurring as fillings along fissures in the altered biotite. As in all Andean diorites of more acid composition, epidote is abundantly present in late crystallized grains, partly of an irregular form, partly sharply idiomorphic. The colour is in the first-named type clear greenish-yellow to colourless, in the latter again more gray or colourless.

In the same locality was found an abundance of boulders of a more granitic type, which probably form the inner parts of the big Island. This rock closely corresponds to the adamellitic granites described by NORDENSKJÖLD and represents the most acid variety observed by the present author and may therefore also be described.

Sp. 214. *Plagioclase-granite.* Isla Londonderry.

The rock is rather coarse-grained with megascopically visible plagioclase, quartz and biotite. The structure is panallotriomorphic. The composition is: plagioclase, potash-felspar, quartz, chloritized biotite, muscovite, epidote, apatite and small quantities of magnetite. The plagioclase is clear, only occasionally slightly saussuritized. It has no zonar structure. The composition is about 30 % An. The potash-felspar is perthitic. The femic components are highly subordinated (< 15 %).

The chemical composition of this rock is seen from the following analysis, carried out by L. LOKKA (1, Tab. X).

The composition is remarkable on account of the high content of alumina, which indicates a very high percentage of felspar in the rock. Compared to the high SiO_2-content the potash percentage is rather lower than in the analysis

TABLE X.

I.		Norm.		
SiO_2	69.33	Qz.	24.60	
TiO_2	0.36	Or.	10.01	
ZrO_2	0.01	Ab.	44.01	Sal. 95.30
Al_2O_3	17.05	An.	16.68	
Fe_2O_3	0.82	Cd.	0.51	
FeO	1.10	Hy.	1.66	Fem. 3.94
MnO	0.06	Mt.	1.16	
MgO	0.42	Il.	0.61	
CaO	3.34		99.24	
BaO	0.05			
Na_2O	5.21			
K_2O	1.66			
P_2O_5	trace			
$H_2O +$	0.86			
$H_2O -$	0.05			
	100.32	I, 2, 4.		

1. Plagioclase-granite, Isla Londonderry. Anal. L. LOKKA.

earlier published by NORDENSKJÖLD. In other words there is no regular connection between the acidity and the alkali relation of the Andean dioritic rocks. This can also be stated at the microscopic investigations, which often give very different amounts of potash-felspars and plagioclase in rocks with about the same quartz percentage.

A rock-type which petrologically is closely connected with the augite-biotite-hornblende diorite from Isla Duntze, but contains more potassium in the form of K-felspar, was found on the small island in Canal Brecknock, known as Isla Nelson. It differs, however, from the first-named, both in megascopic appearance and the field relation. The rock is very even-grained and there are on the island no indications of differentiation. The colour is gray and on account of the small difference of colour between the different mineral constituents the rock is of a strange, almost effusive aspect. Both the plagioclase and the quartz are of the same clear gray colour, only the lustrous seams of mica contrast with the other components. The microscopic appearance is described below (Fig. 1, Pl. XXVII).

Sp. 33. *Augite-biotite-hornblende diorite.* Isla Nelson, Canal Brecknock.

The megascopical aspect of the rock is shown by Fig. 3, Pl. XXVII. The structure is hypidiomorphic, the early separated plagioclase grains have a fairly good crystal-form. The later crystallized felspar forms a ground-mass-like matrix, together with the other salic components. The composition is interesting because of the fairly equal amounts of the femic main-components. The minerals are: plagioclase, quartz, KNa-felspar, biotite, augite, hornblende. In smaller quantitities there further occur chlorite, magnetite, epidote, apatite, titanite and pyrite.

The plagioclase shows a beautiful zonar structure, with rather strong recurrence. The basic kernel generally is rounded and obviously resorbed before the outer shells were crystallized. It contains 45 % An, and generally is covered by irregular fractures which give it a glassy appearance. — This phenomena has, as known already, been described by STELZNER. — The composition of the outer shell is 33—35 % An. Inclusions of epidote are frequently seen in the basic parts, often in the shape of rings along certain zones. The extinction is often in some degree uneven. Twinnings according to the Carlsbad, pericline and albite laws are well developed.

The potash-felspar is an anorthoclase. The irregularly formed grains are quite clear, with the exception of a slight brownish turbidity. Perthite striation and twinning-lamellation are absent.

Hornblende and augite occur generally together; the last-named mineral has crystallized earlier. The hornblende is rather light-coloured, brownish-green with. $\gamma : c = 14°$. The augite is colourless, in most grains turbid, through a secondary crystallization of hornblende. In the present stage the rock only contains one pyroxene. So far as the author has seen there is in none of the Andean dioritic rocks pyroxene of two generations. There are, however, as we have seen from Isla Duntze, indications which show that enstatite or orthaugite originally also occurred. These indications are small agglomerations, evidently altered bigger crystals, consisting of light-greenish cummingtonite amphibole. Another alteration often seen is the alteration of the hornblende into thread-like anthophyllite, but this of course belongs to a later stage of the crystallization, contemporaneous with the crystallization of chlorite and epidote.

The biotite is generally clear brown in colour, though in some grains it is completely chloritized. In connection with the chloritization there is generally a crystallization of epidote along the fissures in the mineral.

Titanite occurs as rather big euhedral crystals.

The chemical composition of this rock is shown by the analysis Table XI, made by Dr. L. LOKKA.

TABLE XI.

1.		Norm.		
SiO_2	62.65	Qz.	17.40	
TiO_2	0.74	Or.	18.35	
ZrO_2	0.03	Ab.	24.63	
Al_2O_3	16.13	An.	21.68	Sal. 81.06
Fe_2O_3	2.16	Di.	5.74	
FeO	3.30	Hy.	9.51	
MnO	0.09	Il.	1.37	Fem. 21.21
MgO	2.76	Mt.	3.25	
CaO	5.69	Ap.	0.34	
BaO	0.05		102.27	
Na_2O	2.89			
K_2O	3.11			
P_2O_5	0.15			
F	0.20			
$H_2O +$	0.18			
$H_2O -$	0.11			
$\div O = F_2$ 0.08	100.24	II, 2, 3, 3.		

1. Augite-biotite-hornblende diorite, Isla Nelson, Canal Brecknock. Anal. L. LOKKA.

The composition differs from that of the corresponding rock of Isla Duntze through the higher content of quartz and the salic components in general. The high content of potash-felspar grades the rock into the monzonite series.

The Andean diorites — described in the foregoing — give a rather good picture of the character of the rocks in the outer parts of the area, where the deepseated character still is indisputable. Only the kind last described shows features which are not quite typical of true abyssal rocks.

In the following a description will be given of a number of types, mainly derived from the e a s t e r n s e c t o r o f t h e A n d e a n d i o r i t e - a r e a, This is not connected with the main body of the rock-complex, and the rock-

---

EXPLANATION TO PLATE XXVII.

Fig. 1. Augite-biotite-hornblende diorite. Isla Nelson, Canal Brecknock. Magn. 14 ×, Nic. +.

Fig. 2. Lime-natron granite with slightly saussuritized plagioclase and chloritized biotite as dominating femic component. Isla Londonderry. Magn. 20 ×, Nic. +.

Fig. 3. Augite-biotite-hornblende diorite, Isla Nelson. The same rock as fig. 1.

EXPLANATION TO PLATE XXVIII.

Fig. 1. Hornblende gabbro-diorite with idiomorphic, prismatic hornblende crystals and An-rich plagioclase. (The megascopic aspect of the rock is shown on Fig. 4, Pl. XXII.) Puerto Santa Rosa, N-coast of Isla Navarino. Magn. 20 ×, Nic. ‖.

Fig. 2. Diorite with strongly zonary-built and rounded plagioclase crystals. The quartz is slightly granulated. Bahia Cascada, N coast of Isla Gordon. Magn. 10 ×, Nic. +.

Fig. 3. Microgabbro with ophitic structure. Dike penetrating the hornblendite at Bahia Fleurais, S. coast of Isla Gordon. Magn. 20 ×, Nic. ‖.

Fig. 4. Hornblende-porphyrite. Lamprophyric dike cutting the gabbro. The dominating mineral is a light-green hornblende, and plagioclase. Abundant epidote is generally present. The rock-type is very abundant within the Andean diorite series. Fleurais bay. Magn. 15 ×. Nic. ‖.

Fig. 5. Diorite porphyry. Boundary facies of the Andean diorite with phenocrysts of plagioclase, hornblende and augite. Seno Icy, E coast of Isla Santa Ines. Magn. 15 ×, Nic. +.

Fig. 6. Lamprophyric dike belonging to the Andean diorite series. Phenocrysts of lightgreen zonar hornblende, augite, and olivine. The white spots are partly calcite, partly analcite. Canal Murray, Peninsula Dumas. Magn. 17 ×, Nic. ‖.

1

2

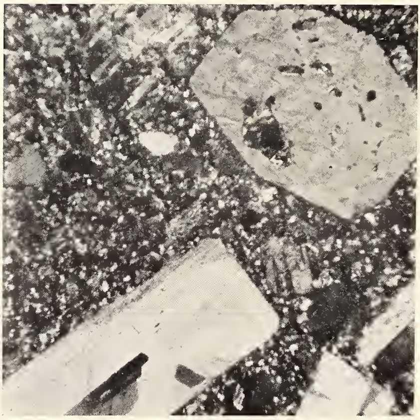
3

1

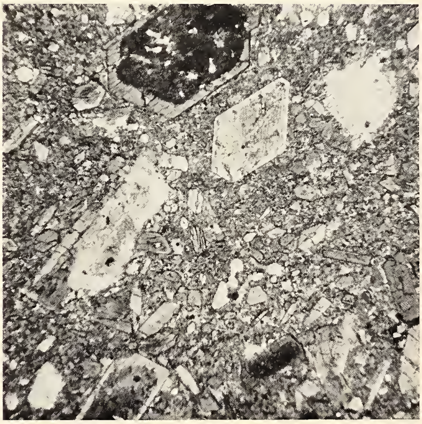
2

3

4



5



6

types therefore can be expected to be of a somewhat varying aspect. They derive from localities mainly situated along the inner boundary of the diorite area. In fact, we have some features which are very typical of these rocks and which only in less degree can be found among those from the inner parts of the batholith. These features generally are structural; the chemical composition does not seem to show any difference of importance, though the sequence of crystallization varies owing to different physical conditions.

In most cases the rocks described in the following have a little more fine-grained character. The hornblende generally forms elongated or needle-like idiomorphic crystals, probably a consequence of more rapid crystallization. The plagioclase is always characterized by a strong, frequently extremely strong (up to 42 well individualized zones have been observed) recurrent zonar-structure, with »glassy» resorbed kernel. Only the latest crystallized portion is of a more homogenous composition. From a mineralogical point of view the hornblende-bearing types predominate. Biotite occurs often in small quantities, pyroxene more rarely (Fig. 1, Pl. XXVIII and pp. 166 and 169).

Mechanical influence is often seen, indicating that movement has taken place in a higher degree in the inner zone than in the outer one during and after the crystallization.

Isla Clarence.

The diorite-area of Isla Clarence seems to form a separate apophysic batholith, which, as far as is known, does not directly connect with the big Andean diorite-area farther south. It lies already on the inner side of the Central Cordillera, and it is therefore not unexpected that the diorites are partly rather deformed by orogenetic influence.

Around Bahia Beaubasin (*cfr.* p. 40) a medium-grained gray diorite predominates. The rock is generally not homogenous, but contains abundant dark inclusions and »Schliers» consisting of earlier crystallized basic portions of the magma and also remnants of assimilated older schists. A parallel-structure due to deformation is seen in some places, but is completely absent in others.

Sp. 294 and 295. *Dark hornblende diorite.* Bahia Beaubasin. Isla Clarence.

Megascopically the predominant components are dark, almost black, hornblende in elongated, idiomorphic crystals, and white plagioclase. The structure is hypidiomorphic. The composition is hornblende, plagioclase, biotite, quartz, magnetite, titanite, epidote and apatite, occasionally also muscovite. The minerals are enumerated in the order of abundance.

The plagioclase occurs as well developed crystals with recurrent zonar structure and twinning according to the albite, Carlsbad and pericline laws. The composition of the kernel is 55 % An, of the outer zone 38 % An. The hornblende is a common green hornblende with $\gamma : c = 17$—$18°$. Quartz is present only in comparatively small quantities, in allotriomorphic slightly undulose grains. Titanite occurs abundantly as sharply idiomorphic rhombic crystals. Of late-crystallized components epidote is the most important. It generally occurs in connection with hornblende and seems partly to replace it. It also occurs as a small-grained pigment, together with sericite, as an alteration-product of plagioclase.

In more acid types there is often found added potash-felspar, which, if the rock has traces of mechanical alteration, forms a myrmekitic intergrowth with quartz (Sp. 302). Contemporaneously the quartz content becomes greater and the plagioclase is more rich in albite, the kernel being only 33 % An, the outer zone 17—18 %.

The already megascopically deformed varieties Sp. 298 and 299 are of similar mineralogical composition, but the biotite- and muscovite-percentage has undergone a marked increase. Also epidote occurs in great abundance. The plagioclase contains 33 % An, and the hornblende is darker green with a smaller extinction angle ($\gamma : c = 12°$). The quartz is crushed up along moving zones and very undulose, and the mica-flakes are parallel-orientated. The plagioclase mostly proves to be very resistant and has been very little altered.

Isla Gordon.

On the north coast of Isla Gordon there is an isolated diorite-area of the same kind as that described in the foregoing. Also here the mechanical influence is rather conspicuous, and the matrix between the big plagioclase crystals is sometimes almost granulated.

At Bahia Cascada, whence the specimens investigated by the present author derive, the rock is medium-grained, almost as coarse as in the central parts of the batholith, and very homogenous.

Sp. 203—204. *Hornblende-biotité diorite.* Bahia Cascada. Isla Gordon.

The composition is plagioclase, hornblende, biotite, quartz, titanite, epidote and apatite. The structure is characterized by big, in part well individualized, plagioclase-grains with a more fine-grained, sometimes granulated matrix. Also quantitatively the plagioclase is the dominating mineral. It has an extremely strong recurrent zonar structure, which is shown on the micro-

photograph Fig. 2, Pl. XXVIII. The number of different zones is very great and almost resembles the annual rings in wood. At this locality there can be distinguished three more conspicuous stages in the development of the crystals, usually marked by small epidote-inclusions of the same kind as are seen in the innermost, anorthite-rich kernel of the crystal. The older parts of the plagioclase-grains are very rounded and often penetrated by fissures, healed up with more acid plagioclase, showing that the rock has been influenced by mechanical stress during the crystallization. The innermost parts are further sanidine-like. The twinnings are very well developed. Owing to the zonar structure, the composition varies to a considerable extent. In the outer part it is about 34 %, in the innermost 43 %. The h o r n b l e n d e is very dark green ($\gamma : c = 17.5°$). Besides this common hornblende there also occurs a more bluish-green type with the following absorption: γ, dark bluish-green $>$ β, brownish-green $>$ α yellowish-green, $\gamma : c = 14°$. The b i o t i t e is always very dark-coloured, with absorption from dark grayish-brown (almost black) to light brownish-yellow. T i t a n i t e in big, gray, sharply idiomorphic crystals is present in great abundance.

In spite of the traces of mechanical alteration in the rocks of Bahia Cascada, they differ in a high degree from the strongly deformed granitic rocks at Ventisquero Italia on the opposite shore of Canal Beagle, and there must be either a tectonical discordance between them, or they derive from a quite another stage of magmatic intrusions in the Cordillera. (*cfr.* also p. 119).

Of the igneous rocks on the south coast of Isla Gordon at B a h i a F l e u r a i s, which also undoubtedly belong to the Andean diorites, the h o r n b l e n d i t i c rocks are of particular interest. They are, after all, not the most widespread type, the main part of the occurrence consisting of a coarse-grained hornblende-diorite or gabbro-diorite, but they are the most characteristic. In several places the hornblendite becomes very coarse-grained, with hornblende crystals of more than 2 cm. size (Sp. 43).

The main constituents of the rock are green hornblende and, in smaller quantities, megascopically light-yellowish-green epidote and plagioclase. In spite of the ultrabasic composition of the rock, the last-named constituent is comparatively acid with 34 % An, consequently corresponding to the more acid parts of the plagioclase of the common Andean diorites. This may partly depend upon most of the lime in the rock having entered into hornblende and epidote, but is probably also due to the differentiation of this rock-type (*cfr.* p. 197).

The h o r n b l e n d e of the rock is a rather normal green hornblende. The orientation is $\gamma : c = 17°$. The absorption is γ (dark bluish-green) $>$ β (brown-

ish-green), $> \gamma$ (yellowish-green). The composition is, however, not homogenous and particularly the outer part of the individuals, and also often small, late crystallized grains, are of a lighter-coloured type, usually bluish green, indicating a considerable percentage of natron. The refraction of light was determined to

$$\alpha = 1.641 \pm 0.003, \beta = 1.661 \pm 0.003, \gamma = 1.673 \pm 0.003.$$

The epidote has n $>$ 1.740.

Besides the minerals named above, the rock contains magnetite in big crystals, and sometimes also calcite. In the most coarse-grained, almost pegmatitic variety, a white mineral was observed occurring as late crystallized grains between the hornblende crystals. This mineral shows the optical character of datholite.

Peninsula Dumas.

The diorite area on the north coast of Peninsula Dumas corresponds as regards situation with the diorite area on the north coast of Isla Gordon. The occurrence was also observed already by Lovisato, who *i.a.* described a number of contact rocks containing garnet and andalusite from the tracts around the north end of Canal Murray. The present author studied the contact with the country-rocks at the small bay inside »los Islas Campamento». Here the diorites penetrate strongly altered mica-rich schists, probably belonging to the Yaghan formation. The contact is a typical assimilation-contact, and the diorite forms migmatites with the schist. Red garnet was observed as a contact-mineral.

The diorite at this place is for the most part a medium-grained hornblende-diorite, which, however, grades into an augite-bearing basic gabbro-diorite. The first-named is mainly composed of hornblende, plagioclase (40—43 % An) with sparse biotite, magnetite and epidote. The plagioclase is interesting, both because of the strong recurrence, and because of the aspect of the innermost kernel of the grains. The last-named consist of several resorbed, highly saussiritized fragments of a bigger kernel, which has been destroyed during the course of crystallization.

The *gabbro-diorite* (Sp. 51) consists of basic plagioclase, pyroxene, hornblende, magnetite, quartz (sparsely) titanite and apatite. The structure is panallotriomorphic. All the mineral components are very clear and unaltered. The plagioclase occurs as broad, irregularly limited grains, without

zonar structure. The composition is 62 % An. Twinnings according to the albite and pericline laws abound, such according to the Carlsbad law occur more rarely. The pyroxene is a diopsidic, greenish-gray augite with $\gamma : c = c.\ 45°$. The hornblende is clear brownish-green, and often forms a corona around the pyroxene. The orientation is $\gamma : c = 18°$.

Farther west in the same diorite area, inside Rocas Perones, the rock-ground is composed of even-grained diorite, resembling the more acid type described above (Sp. 165, 166). It contains a considerable amount of KNa-felspar in addition to the components of the last-named rock. The composition of the plagioclase is 33—43 % An, and it shows well developed recurrent zonar structure. Traces of mechanical influence sometimes occur in connection with this myrmekitic intergrowth of felspar and quartz.

Isla Navarino.

The diorite area of the north coast of Peninsula Dumas continues along the north coast of Isla Navarino. Also here we find both normal hornblende-diorites and more basic gabbro-dioritic varieties. A beautiful hornblende-gabbro occurs at Puerto Santa Rosa (Sp. 163). The rock is characterized by the densely scattered, prismatic, black hornblende crystals (0.3 to 0.5 cm in length) (Fig. 1, Pl. XXVIII). The only salic component is the plagioclase, which is very strongly zonally built, but without recurrence. The composition varies in the inner and outer zones as much as from 33 to 54 % An. In the kernel there are fragments of a still more basic plagioclase. Also the hornblende is of distinct zonar structure, with the outermost shell bluish-green with $\gamma : c = 13°.5$, the inner parts yellowish-green with $\gamma : c = 17°$. An alteration into chlorite is common. Biotite is not present. Other constituents are epidote, titanite and magnetite. According to a geometrical analysis the quantitative composition is about the following: plagioclase 40.0 % quartz 3.7 %, hornblende 50.1 % and magnetite 6.2 %.

The most interesting diorite area on Isla Navarino is the occurrence at Rio Grandi on the south coast. Here we meet a number of rocks which in many respects differ from the normal series of the Andean diorites and show relations to the alkaline rocks, though they with certainty can be regarded as deriving from the same magma as the first-named.

At the inlet of Rio Grandi the rock-ground consists of medium-grained light reddish coloured rock, which already megascopically shows an alkaline aspect and which under the microscope proves to be monzonite. Together with this occurs a dark, medium-grained gabbro. Breccias with gabbro-inclusions

in monzonite are frequently met with. In addition, there are in the monzonite also inclusions of probably sedimentary origin. They are more fine-grained and show traces of parallel structure or layering.

The petrological character of the different rocks of the complex appears from the following description.

Sp. 75. *Monzonite.* Outlet of Rio Grandi, South Navarino (Microphotograph fig. 1, Pl. XXIX).

Megascopically the rock is coarse medium-grained reddish-gray. The light-coloured components predominate. The mineralogical composition is: plagioclase, anorthoclase, augite, biotite, titanite, magnetite and in small quantities quartz, epidote and sulphides.

The structure is hypidiomorphic. The plagioclase occurs as well individualized crystals, which always have a very characteristic rugged resorbed edge towards the surrounding components (K-felspar and quartz). The potash-felspar is the latest crystallized component and has generally the character of a matrix between the other minerals.

The plagioclase is zonally built with recurrent structure. The composition of the outermost zone is about 25 % An; that of the inner parts 38—40 % An. The percentage of anorthite is consequently about the same as, or slightly lower than that of the normal Andean diorites. The mineral is generally clear and only in a slight degree saussuritized. The extinction is in most grains flamy, due to irregular variations in the composition within the same mineral-grain. Twinnings according to the Carlsbad, albite and pericline laws.

The KNa-felspar is a perthite with rather high percentage of albite, both in the shape of perthite-lamellation and in the shape of chess-board structure. The amount of albite in the grains is not much smaller than the amount of orthoclase. Twinnings according to the Carlsbad law are common. The dark components are less conspicuous. The most important is the pyroxene. Diopsidic augite occurs as irregularly formed grains which generally are slightly elongated. The colour is light-greenish, almost colourless. Absorption is unnoticeable. $\gamma : c = c\ 44^\circ$, $2E = 32^\circ$.

The biotite is strongly pleochroitic, light-yellow to dark reddish-brown. Titanite occurs in great quantities as rather big euhedral grains. Quartz is very rare, and occurs as small irregular spots between the other components. The chemical composition of these rock-types will be seen from the following analysis made by Dr. L. Lokka.

The analysis confirms the conclusions drawn from the microscopic investigations, showing that the rock is a typical monzonite, resembling that of the

TABLE XII.

1		2	3	Norm of 1	
SiO_2	57.59	57.32	56.21	Qz 2.36	
TiO_2	0.83	1.08	0.88	Or 27.24	
ZrO_2	0.01	—	—	Ab 38.77	Sal. 83.94
Al_2O_3	18.33	17.35	18.24	An 15.57	
Cr_2O_3	non	—	—	Di 11.65	
Fe_2O_3	3.00	3.23	3.26	Hy 0.83	
FeO	2.71	4.04	3.69	Il 1.52	Fem. 19.08
MnO	0.15	0.08	0.17	Ap 0.67	
MgO	1.71	2.63	3.38	Mt 4.41	
CaO	5.76	5.87	5.91	103.02	
BaO	0.07	—	—		
Na_2O	4.61	3.53	4.15		
K_2O	4.62	4.06	3.02		
P_2O_5	0.24	0.17	—		
F	0.21	—	—		
H_2O +	0.34	0.55	0.64		
H_2O —	0.13		(CO_2—0.78)		
	100.31	99.91	100.33	II, 5, 3, 2	
—O = F_2	0.09				

1. Monzonite. Rio Douglas, Isla Navarino. Anal. L. LOKKA.
2. Hypersthene monzonite, Monte Mulatto. Anal. M. DIETRICH (ROMBERG, 49.).
3. Orthoclase-gabbro diorite (quartz-bearing) Hurricane Ridge, Crandall Basin, Yellowstone Nat. Park. Anal. S. G. EAKINS. (Geol. Sur. 1899. XXXII, p. 260).

original occurrence in Switzerland. It differs from the last-named in containing a little more alumina in comparison with the silica percentage, but has in other respects all the features typical of the rock-group in question, with an almost equal amount of potassium and sodium.

Besides this pyroxene-monzonite there also occurs a hornblende monzonite which differs from the foregoing in having hornblende instead of pyroxene. The potash-felspar is more dominant and the plagioclase seems to be a little more acid, with 22 % An in the outer zone, 38 % in the kernel. The h o r n b l e n d e occurs as elongated grains with a tendency to idiomorphic limitation. The main-part of the grains consists of a light-green amphibole with the following absorption: γ (light bluish-green) $>$ β (light-green) $>$ α (light yellowish-green). $\gamma : c = 12.5°$. In this mineral there are frequently spots of clear dark-blue hornblende, which evidently replace the former. The extinction angles are small, $\alpha : c = 10—8°$. The absorption is typical of the alkaline amphiboles.

α yellowish-green, β violet-blue, γ dark-blue.

These optical data point to a crossite. Here we consequently have good evidence of the alkaline tendency of the rock-complex.

The gabbro at this place, occurring together with the monzonites, has the following character.

Sp. *73*. *Gabbro*, Outlet of Rio Grandi, South coast of Isla Navarino (Microphotograph fig. 2, Pl. XXIX).

The rock is megascopically medium-grained dark-gray. The mineral composition is mainly: plagioclase, diopsidic augite, hornblende, magnetite, biotite, titanite and apatite. Under the microscope all the mineral components appear very clear. Late magmatic mineralization is almost absent. The structure is panallotriomorphic; the boundaries between the grains are crenelated or sinoid.

The plagioclase is an anorthite with 88—90 % An. Zonar structure is almost lacking. Twinnings according to Carlsbad, pericline and albite laws. Saussuritization occurs but slightly in the innermost parts of the crystals. The pyroxene occurs as rounded grains: γ is light greenish-gray, α and β light yellowish-gray. $\gamma : c = 47^\circ$. As in the monzonitic rocks at this place it

---

EXPLANATION TO PLATE XXIX.

Fig. 1. Monzonite. Hypidiomorphic grains of plagioclase with rugged borders embedded in perthitic KNa-felspar. The dark mineral is augite. Rio Grandi. South coast of Isla Navarino. Magn. 17 ×, Nic. +.

Fig. 2. Gabbro. The main components are basic plagioclase, diopside and magnetite. The rock represents the basic pole of the monzonite series of Isla Navarino. Rio Grandi. Magn. 10 ×, Nic. +.

Fig. 3. Eruptive breccia with basic finegrained inclusion mainly consisting of diopside (left upper corner) in a mediumgrained monzonite. The big dark crystals are hornblende, partly altered into diopside and magnetite. Rio Grande, Isla Navarino. Magn. 10 ×, Nic. ||.

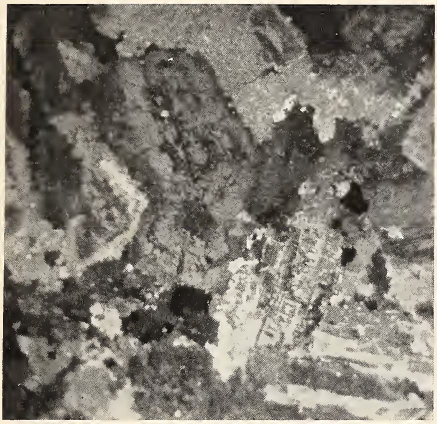
Fig. 4. Spessartite with big phenocrysts of hornblende and small-grained amphibole, augite and plagioclase in a glassy groundmass. Isla Duntze, Canal Cockburn. Magn. 15 ×, Nic. +.

EXPLANATION TO PLATE XXX.

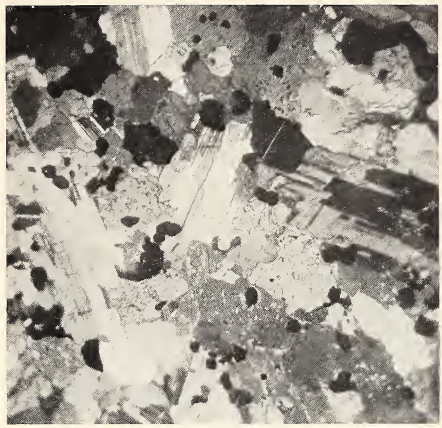
Fig. 1. Eruptive breccia. Bahia Grandi. S Navarino.

Fig. 2. Epidote-biotite diorite. Puerto Olla, Canal Beagle. The chemical composition is about the same as that of No 1.

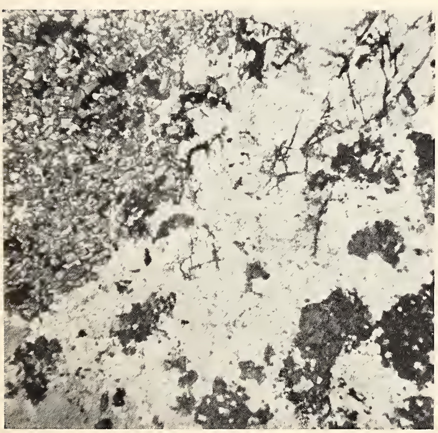
Fig. 3. Olivine gabbro. Isla Duntze, Canal Cockburn.



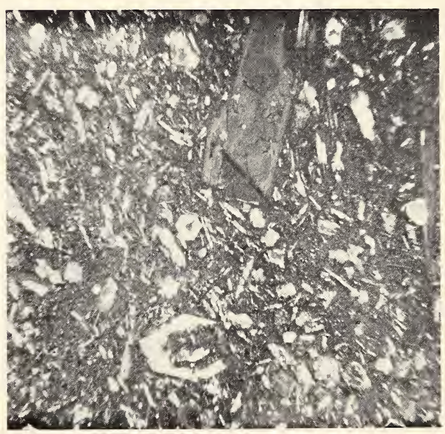
1



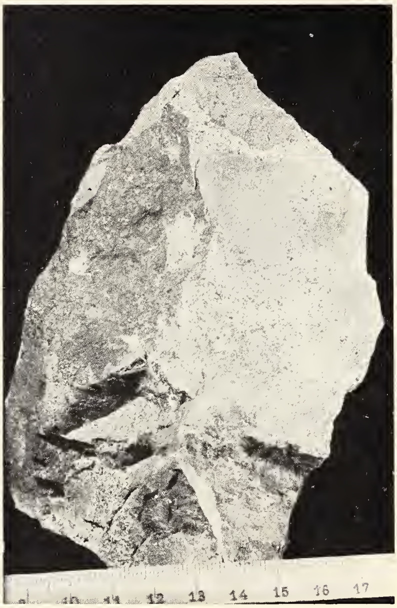
2



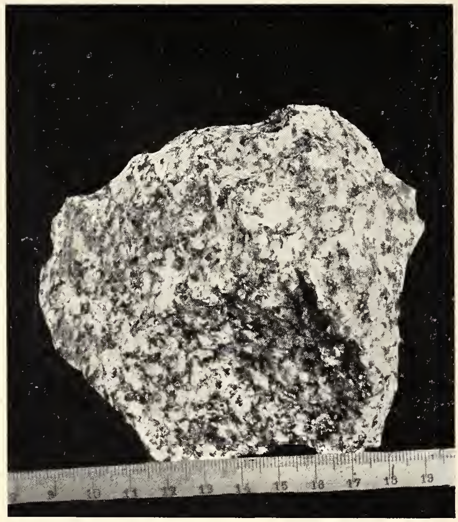
3



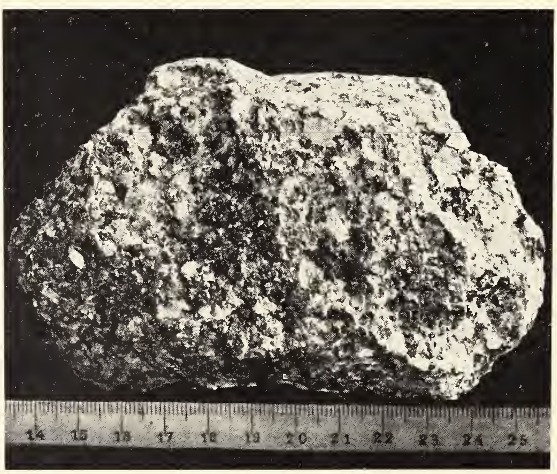
4



I



2



3

seems to be a d i o p s i d i c a u g i t e. H o r n b l e n d e occurs in slightly smaller quantities than the augite. It is light brownish-green. The absorption is: α yellowish-green, β yellowish brown-green, γ brownish-green. The mineral seems to have crystallized rather late as big individuals, often surrounding idiomorphic plagioclase crystals. The b i o t i t e is always very strongly resorbed and generally partly altered into epidote and sericite (not into chlorite). The colour of the unaltered mineral is light-yellowish to copper-reddish brown. M a g n e t i t e occurs abundantly in big, rather late crystallized grains.

The chemical composition will be seen from analysis 1. Table XIII made by Dr. L. Lokka.

According to the analysis also the basic line, in the monzonite group of Isla Navarino, shows a composition which does not correspond to the basic components in the normal diorite series, *e.g.* the gabbro of Isla Duntze. Particularly the very high CaO-percentage is conspicuous, as well as the comparatively low percentage of MgO. As a matter of fact the same tendency could already be seen in the monzonites, and it appears mineralogically in the diopsidic character of the pyroxene. The typical feature of the series is in other words a comparatively high content of potassium and lime as compared with the silica percentage.

TABLE XIII.

1.		Norm.		
SiO_2	39.84	Or.	3.34	
TiO_2	3.11	Ab.	7.34	
Al_2O_3	17.32	An.	41.70	Sal. 52.38
Fe_2O_3	7.37	Di.	5.89	
FeO	7.05	Wl.	14.73	
MnO	0.21	Ol.	8.85	
MgO	5.28	Ap.	1.01	Fem. 52.38
CaO	17.21	Mt.	10.67	
Na_2O	0.89	Il.	5.93	
K_2O	0.58		99.46	
P_2O_5	0.43			
S	0.07			
F	0.18			
H_2O+	0.72			
H_2O-	0.11			
	100.37	III, 5, 5; Kebekase.		
$-O=F_2$	0.08			

1. Diopside-hornblende gabbro. Rio Douglas, Isla Navarino. Anal. L. Lokka.

Of particular interest is the petrological character of these eruptive breccias, which is suited to throw light on the origination and peculiar differentiation of the monzonite series at this place.

The breccia consists of a medium-grained light-coloured monzonite rock, in which there are inclusions of dark, fine-grained material (*cfr.* Fig. 2, Pl. XXX). Microscopic investigation shows that the coarse-grained matrix has almost the same character as the monzonites described above, though the amount of potash-felspar generally is smaller. It contains big grains of both diopsidic augite and green hornblende. The plagioclase has 28—30 % An. The hornblende is of the same kind as in the monzonite, sometimes also darker, with $\gamma : c = 16°$. The brownish-green to light yellowish-green pyroxene has $\gamma : c = 42°$. The hornblende-grains are often surrounded by a corona of small diopside grains, and in many crystals it is obvious that the hornblende is altered into diopside and consequently here is older than the first-named mineral. Contemporaneously with that alteration a newcrystallization of magnetite in small rounded grains can regularly be observed. Evidently the hornblende was richer in iron than was the pyroxene.

This sequence of crystallization would be rather unexpected in a normal igneous rock, and the author believes that it in fact hardly can be interpreted as a primary crystallization out of a magma.

An investigation of the fine-grained dark inclusions — some cm to one decimetre in diameter — in the breccia-like varieties of the rock-complex shows that these inclusions mainly consist of small rounded grains of diopside (*cfr.* Fig. 3, Pl. XXIX) densely clustered together with small quantities of plagioclase and quartz. Magnetite also is very abundant, generally occurring together with small quantities of light-yellowish biotite.

The structure undoubtedly gives more the impression of a contact-metamorphic rock, *e.g.* so called »skarn-rock» or a hornfels, than of a normal igneous rock. The natural explanation of the origin seems to be that it is formed by assimilation of a lime-rich sediment into a dioritic or a still more basic magma. This seems the more probable, as we obviously here are close to the roof of the batholith, and some km farther north meet the carbonate-rich tuffs of the tracts of Rio Douglas. The diorite-magma has evidently intruded into the sediments and reacted with included fragments from which lime has been absorbed, giving rise to diopsidic pyroxene. It appears that the assimilation of lime has partly happened after the crystallization of hornblende in the eruptive breccias. Therefore the igneous rock here has first crystallized in the normal order with hornblende and biotite; in the ground-mass there has later been an enrichment of lime, which has caused the alteration of hornblende

into diopside and contemporaneously the precipitation of magnetite. (*cfr.* Fig. 3, Pl. XXIX). The new-crystallized diopside is always very fine-grained, and of the same kind as in the altered inclusions in the breccia.

These reactions as a matter of fact seem to explain the small amount of silica in the rock, though not the high content of potassium. An enrichment of potassium is on the other hand a phenomenon which is well-known in connection with many extremely lime-rich magmas. Independently of the explanation of the origin of the monzonites here in question, they offer an interesting example of alkaline rocks deriving from magmas of a Pacific type.

In contrast to the rocks of Rio Grandi, the diorites from the inner parts of Isla Navarino, north-west of Puerto Douglas, are normal quartz-diorites (Sp. 66, 67). They are comparatively light-coloured medium-grained rocks, with hornblende as the dominating femic component. The structure is hypidiomorphic. The mineralogical composition is: plagioclase, hornblende, biotite, quartz, magnetite, pyrite, titanite, apatite and epidote. The plagioclase occupies about 65 % of the rock. It is zonar, with 55 to 57 % An in the kernel, 36 % in the outer zone. The average composition might be about 40 %. The mineral is very clear and unaltered. The hornblende is light-green ($\gamma : c = 12°$) with bluish-green margin. No potash-felspar was observed.

The Andean Diorites of the Southern Side of Isla Hoste.

As the detailed descriptions by Hyades show, the rock-ground of Isla Hoste, from about Bahia Tekenika on the east side to Bahia Fouqué on the north-west side, consists of dioritic to granitic rocks greatly resembling those described in the foregoing chapters. Also in these tracts there is a comparatively strong variation at every locality, with types from granitic rocks to basic gabbros and diabasic varieties. The descriptions clearly indicate that particularly along the contact are found porphyric varieties of diorite, with idiomorphic plagioclases, showing strong recurrent zonar structure (Isla Packsaddle, Orange Bay). In the southernmost parts, where the contact of the batholith was fairly distant, rather acidic granitic rocks abound (Seno Ano Nuevo, at Seno Talbot in the south-west part of the islands).

It is of course difficult to get an exact picture of the quantitative relation of the different rock-types, though it is evident that the intermediate types, *i.e.* normal diorites and granodiorites, are the most widespread, and represent the main-rock of the region.

THE DIKE ROCK SERIES.

As already shown in the local descriptions, dike rocks occur abundantly within the Andean diorite area. They seem mainly to represent diaschistic differentiations, representing the last erupted melts of the magma. Their composition does not exactly coincide with that of the rocks of the main series, but often approaches it very closely. The basic dikes are dominant.

Pegmatitic dikes and aplites are rare, and have been found only in exceptional cases. They generally consist of coarse-crystallized light-red potash-felspar and quartz. The scarcity of pegmatites, in spite of the high content of quartz, evidently depends on crystallization at a comparatively high level, where the volatile components had a possibility of escaping at an early stage of the crystallization. The Andean diorites also in this respect resemble the supercrustal, effusive rocks.

The dark, lamprophyric dikes generally belong to the odinite-spessartite series. They are fine-grained to dense rocks, with megascopically visible black hornblende-needles, sometimes also containing augite and plagioclase. The main constituents are partly hornblende and plagioclase, partly hornblende, augite and plagioclase, in some cases also olivine. The hornblende is always idiomorphic with long-prismatic habit of the common type with 110, 010, 111 and 001. It generally occurs in two generations: 1) as big phenocrysts 2) as small crystals in the ground-mass. The commonest type is of a grayish brown-green colour. Usually the crystals show a zonar structure with a dark outer zone and a lighter-coloured inner one. Also recurrence is sometimes seen. The kernel generally is of more tremolitic composition; the outer zone is rich in actinolite. The extinction of the first-named is $\gamma : c = 20°$, of the latter $10°—12°$; in many cases $17°$. In some specimens (particularly in more acidic varieties) the outer actinolitic zone is light-coloured.

In contrast to the hornblende, the augite-crystals are as a rule strongly resorbed, and evidently derive from an earlier stage of the crystallization. They are sometimes altered into hornblende. The resorbed character is still more conspicuous as regards the olivine, of which generally only rounded fragments are left. Light-yellowish biotite is present only in small quantities; in fine-grained or glassy varieties it is generally absent. Small magnetite-grains often play a fairly important role, especially in the ground-mass. The plagioclase is absolutely predominant among the light components. In most cases it occurs only in the ground-mass, in the shape of small elongated crystals or irregular grains. The composition of the first-named is about 26—25 % An.

At several places (Isla Duntze, Bahia Fleurais) some of the dikes have a spilitic character, and consist mainly of light-greenish amphibole and albitic plagioclase. The first-named has rugged edges and is in some degree altered. The inner parts consist of the normal grayish-green hornblende, the outer is often of a light bluish-green type, evidently containing some sodium. The albite, together with quartz, forms the ground-mass between the hornblende-crystals and shows no crystal form. Epidote is regularly present, often in great quantities replacing the amphibole. Also more or less chloritized biotite is generally found.

These varieties evidently represent dikes rich in volatile components, which have crystallized at a low temperature.

The chemical composition of the lamprophyric dikes is characterized by a greater enrichment in the femic oxides than that of the main series and contemporaneously also higher alkali-content. As a typical example the following analysis by Dr. LOKKA is given (Table XIV). It is of a dense black dike from Isla Duntze, with megascopically visible small, black, lustrous hornblende needles. Under the microscope there are further visible augite and small plagioclase lests, biotite and rounded magnetite grains. The ground-mass is for the most part glassy. The structure of the rock is shown in Fig. 4, Pl. XIV.

TABLE XIV.

1.		2.	norm of 1.		
SiO_2	46.98	45.15	Or.	12.23	
TiO_2	2.38	2.80	Ab.	26.20	
Al_2O_3	16.60	15.39	An.	25.02	Sal. 63.45
Fe_2O_3	3.87	2.76	Di.	0.68	
FeO	6.24	5.64	Ol.	18.22	
MnO	0.15	0.14	Wl.	6.96	
MgO	6.89	6.38	Mt.	5.57	Fem. 35.99
CaO	8.59	8.83	Il.	4.56	
Na_2O	3.12	2.67		99.44	
K_2O	2.09	2.77			
P_2O_5	0.01	0.56			
H_2O+	2.68	2.85			
H_2O-	0.30	—			
	99.90	100.21	III, 5, 4, 3; Auvergnose.		

1. Spessartite, Isla Duntze, Canal Cockburn. Anal. L. LOKKA.

2. Augite-amphibole-vogesite. Fourmile Creek, Castle Mountains, Montana. Weathered with 4.27 % CO_2 (ROSENBUSCH-OSANN, Gesteinskunde, p. 332).

A comparison with other rocks from the same locality (page 154) clearly shows the lamprophyric character of the rocks now in question, though the relation to the first-named ones is indisputable. An analysis of a vogesite from Castle Mountains, Montana, is given as a comparison, and proves the great similarity between the lamprophyric rocks deriving from potash-rich magmas and from lime-sodium-rich magmas. The lamprophyric restmagmas seem to be identical. As is known, this fact has clearly been proved by the investigations of BEGER (9). The high content of potassium indicates that the dike at Isla Duntze contains this stuff in the vitreous ground-mass.

Of a different type, and possibly of aschistic character, are the diabase-like dike-rocks of the Andean diorite areas. Megascopically they resemble the foregoing rocks, but are more even-grained, without phenocrysts. The structure is ophitic, with short plagioclase-lathes between light-yellowish augite and brownish grass-green iddingsitic mineral. Magnetite is present in abundance. The rocks are less resistant against atmospheric agencies and often weathered. The plagioclase is generally turbid and in some degree saussiritized. The aspect of these rocks is shown by Fig. 3, Pl. XXVIII.

B. THE PETROLOGY AND DIFFERENTIATION OF THE ANDEAN DIORITES.

The general features of the petrology of the Andean diorites of the Southern Andes were first outlined by O. NORDENSKJÖLD (41). He principally pointed out the transitional position of the granitic rocks of the series, between the potash-bearing rocks and the pure dioritic rocks. The want of analysis and the small number of localities investigated has, however, made our knowledge of the petrological conditions, which is principally based on the descriptions of NORDENSKJÖLD and HYADES, comparatively uncertain.

According to the observations quoted above, the Andean diorites of Tierra del Fuego can be divided into the following main-types forming a complete series or tribe.

1. Plagioclase granite (adamellitic). The rock contains abundant (> 20 %) quartz and potash-felspar (> 20 %). Plagioclase occurs in quantities about equal to the potash-felspar. The dominant femic component is biotite. The anorthite-percentage of the plagioclase is 17—28 %.

2. Quartz diorite. The dominating mineral components are plagioclase (up to 40 %) KNa-felspar, quartz, hornblende, sometimes also pyroxene and biotite. The potash-felspar is generally present only in small quantities.

The composition of the plagioclase is about 43—47 % An in the kernel. In the outer zones it almost corresponds to the plagioclase of the granitic components. With the exception of the outermost parts the crystals are usually strongly zonal.

With a decreasing quartz-percentage the rock passes over into the diorites and gabbro-diorites with more than 50 % femic components, of which hornblende still is the most common. The plagioclase is mainly the same as in the quartz-diorites, though strongly resorbed fragments of a plagioclase with over 60 % An can often be seen in the kernel.

3. Gabbro. The rock consists mainly of basic plagioclase with 60—80 % An and about equal quantities of pyroxene and hornblende respectively. Also olivine is often present. The pyroxene is generally a clinoenstatite, pale lilac in colour. In the most basic components the hornblende is brownish, basaltic.

The rocks named above and their transitional forms form the main series of the Andean dioritic stem. From this derive some branching series, of which the monzonites of Isla Navarino and the hornblenditic rocks have been described above. The former are characterized by an enrichment of potash-felspar, and very low quartz percentage. The plagioclase and also the pyroxenes of this series are characterized by the high percentage of calcium. The latter consist mainly of hornblende and are especially rich in iron.

The petrology of the dioritic rocks and more particularly the relation between the rock-varieties occurring and the sequence of crystallization has of late often been discussed from general theoretical points of view, in especial by BOWEN (12) and GOLDSCHMIDT (29), and the process of crystallization of South American dioritic rocks by BACKLUND (6). We need not here repeat the well known conclusions of the authors named above, which generally are applicable also to the rocks described in the foregoing chapters.

The description clearly proves that there is a close relationship between the sequence of crystallization and the rock-types occurring, even if the scheme does not hold strictly good as a consequence of varying physico-chemical conditions in different parts of the big igneous complex at the cooling.

The crystallization of the Andean diorites begins with olivine, the first of the main components to form as a mineral. This mineral is only found in the most basic rock-components of the series, generally together with pyroxene, and anorthite-rich plagioclase. The first pyroxene to crystallize is a clinoenstatite. Rhombic pyroxene has not been observed. During a later state, and generally also in more acid varieties,

diopsidic augite is formed. As a rule the two types of pyroxene do not occur together in the same rock. The earlier crystallized pyroxene is altered to cummingtonitic amphibole in varieties containing the later type. In the main series of the stem hornblende is still later than the diopside. In the intermediary and acidic varities it frequently is the only femic component. Generally also biotite is present in varying quantities. Also the hornblende has a differing composition, a consequence of the composition of the rock. The dominating type is common green hornblende ($\gamma : c = 17^\circ$—18°). In more acidic varities, crystallized at lower temperatures, the mineral has a tendency to change into actinolite, which mineral often forms the outermost zone of the hornblende-crystals. The ultrabasic end-members of the series sometimes contain brown basaltic hornblende, which, however, also for the most part is originated through alteration of earlier crystallized pyroxene.

The hydrothermal stage is particularly well represented in the acidic varieties. During this stage, there was first of all a crystallization of epidote. This mineral is often found surrounding the hornblende-crystals and is originated on the coast of the last-named. Along zones of movements in the rock there is regularly an intense epidotization. During the same stage the biotite is replaced by chlorite. The epidote is of slightly varying composition, depending on the stage at which it was originated. The earlier formed grains, intimately connected with the hornblende, are generally a clear-green, pleochroitic pistazite. Later on there is frequently formed a grayish, almost colourless clinozoisite, occuring as sharp idiomorphic grains. The kernel in the last-named often consists of the green, pleochroitic type.

The reactions taking place on the crystallization of these minerals have been treated in detail mainly by the authors named above, and they therefore will not be discussed here.

The plagioclase is the most important of the salic components of the rock. The high anorthite-percentage in comparison to the quartz-percentage can be regarded as a typical feature of the Andean diorite series. Also in acidic varieties with more than 20 % quartz the plagioclase first crystallized shows up to 40 % An. This proves that the lime-percentage was high as compared with the sodium-content in the Andean dioritic magma.

A characteristic feature, mentioned by several authors, is the extremely strong zonar structure, which, as pointed out earlier (p. 165), seems to be especially typical of certain parts of the rock-complex. The same crystal varies in some rock-types from about 20 to 45 % An, sometimes also 60 %. The zonar structure is partly continuous, partly

recurrent. In the latter case the mineral gradually changes, from being more An-rich to more Ab-rich, until after a certain stage it suddenly again becomes more An-rich. Contemporaneously the foregoing zone is in some degree resorbed. The resorption is sometimes very strong; often only small fragments with rounded edges remain, especially of the inner basic parts. This reaction generally gives rise to crystallization of epidote and sericite along the contact, and these reaction-minerals will later be included as small rings at the continued crystallization of the felspar-grains.

The recurrence of the zonar structure has often been explained as depending on undercooling in the magma. This may partly be the case with the very small rhythmic variations, but hardly explains the big recurrences with strong resorption, and can also hardly be combined with the gradual, homogenous change in composition within every zone. BACKLUND (6) has shown that the coarse recurrence has a distinct relation to the crystallization of femic lime-rich components. The number of recurrences here is, however, in most of the Andean diorites too big to be explained with the aid of this theory, as BACKLUND also admits.

The facts named above seem to the present author rather good evidence that a reheating of the cooling magma has taken place several times in the course of crystallization. Besides, the corroded, rounded form of the inner zones of the plagioclase indicates such a reheating. Also the glassy appearance of the kernel parts of the mineral-grains, pointed out by STELZNER, is evidently due to this cause. In these crystals the felspar has lost its typical cleavage and is only crossed by irregular cracks, resembling the fissures in glass, etc. Especially the basic kernel parts of strongly zonar plagioclases frequently show this characteristic, which may depend upon a beginning melting of the mineral.

A rhythmic change of temperature in the magma, of the kind which may have occurred in this instance, probably depends upon a rhythmic change of the pressure within the magma, caused by rhythmic departure of gases. Such departure will affect more especially the upper parts of the magma-mass, near the roof of the batholith. As a matter of fact, the field-observations show that the strong, recurrent zonar structure is particularly well developed in the marginal, outer parts of the Andean diorite area, mainly in apophyses from the last-named, which probably were in communication with the earth-surface (p. 164). On the other hand, the inner parts of the complex show less developed zonar-built plagioclase, though the pressure also here in some degree has changed, in consequence of the circulation and gradual departure of gases in the magma-masses. In the basic gabbros the anorthite-rich plagio-

clase as a rule has no zonar-structure, which indicates crystallization at high temperature and at high, even pressure.[1] At the crystallization of the most acidic parts of the magma with Ab-rich plagioclase, the pressure likewise was comparatively constant, because the gaseous components had already in part escaped, and had in part been sublimated and entered into the hydrothermal minerals of the rock.

In accordance with this point of view, we can generally suppose that in the same area the rocks as a rule have the same number of recurrent rings of the same strength. The specimens obtained by the author are not numerous enough to prove the truth of this assumption, but in no case have we found any exceptions to this rule. In some of the Andean diorite areas along Canal Beagle one regularly finds three strong recurrences, evidently corresponding to the same number of eruptions in overlying volcanoes, along a volcanic strike, which seems to coincide with the direction of the present Canal Beagle. The fact that intense volcanic activity has taken place at the time of the intrusions of the Andean diorites is shown by the great abundance of andesitic lavas, etc. in the Cretaceous conglomerates of the Cordillera. It would be of very great interest to investigate wether a correlation can be made between the zonar structure of the intramagmatic plagioclase-phenocrysts of these rocks and the underlying Andean diorites.

An interesting fact, which is easily explained according to the assumptions given above, but which otherwise would be hard to combine with the reaction-principle of Bowen, is the absence of plagioclase-zones of certain composition among the Andean diorites. Thus *e.g.* plagioclase of the composition 45—60 % has been found only in very few cases. The missing members of the plagioclase-series, however, seem to vary in different parts of the area.

The c h e m i s t r y o f t h e A n d e a n d i o r i t e s is well illustrated by the analyses made by Dr. Lokka, which confirm in every respect the conclusions drawn from the microscopic investigations. Table XV gives a collocation of a number of rocks belonging to the main-series of the Andean diorite tribe, and in Fig. 58, p. 183 the same analyses are graphically presented.

In the table No 1 represents an ultrabasic iron-rich member, which resembles the hornblenditic varieties and seems to represent the basic pole of the series. No 6 belongs to the metamorphic cordillera-granites, but joins chemically the same rock-series as the acidic end-member (*cfr.* page 197).

---

[1] The theoretical foundation of this suggestion is newly worked out by W. Wahl, who will in the near future publish a paper on this question.

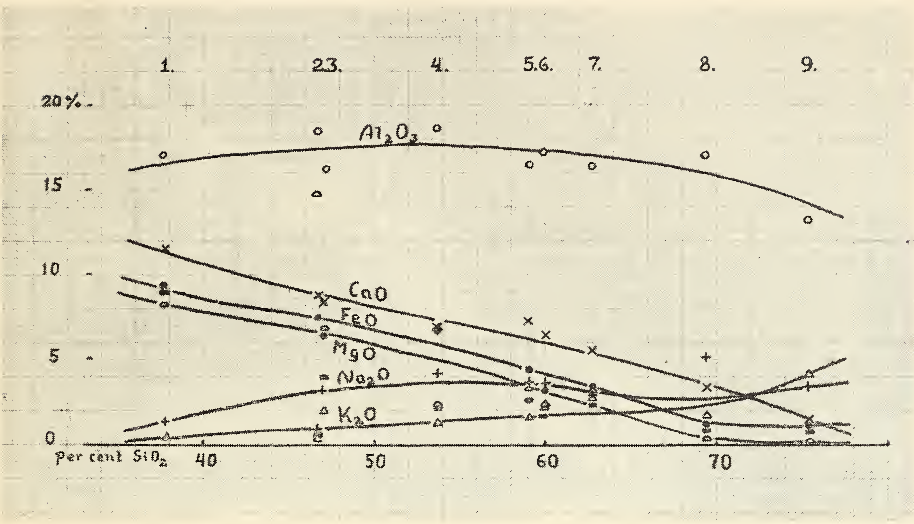


Fig. 58. Variation-diagram of the Andean diorite and Cordillera-granite series. (Weight percentage).

Andean diorites:

1. Magnetite-hornblende gabbro, Isla Duntze.
2. Olivine gabbro, Isla Duntze.
3. Spessartite dike, Isla Duntze.
5. Augite-biotite diorite, Isla Duntze.
7. Augite-biotite » Isla Nelson.
8. Granite, Isla Londonderry.

Cordillera-granites:

4. Mylonite-diorite, Valle Desillusion.
6. Biotite-epidote diorite, Puerto Olla.
9. Gneiss, Ventisquero Jendegaia.

On the whole the main-components change very regularly from one end of the series to the other, and the variation-diagram resembles that of the average in the diorite group (*cfr.* BUDDINGTON, 15). The comparatively low percentage of magnesia and high percentage of lime can be regarded as typical features of the Andean diorite series. The last-named increases more rapidly with decreasing silica-percentage than does the first-named. Generally the change of the percentage of the different oxides runs in an almost rectilinear manner; only the alkalies seem to form an exception to this rule. The proportion between sodium and potassium is not strictly dependent on the silica-percentage. Also in acidic, granitic varieties the sodium-content may be higher

TABLE XV.

	1.	2.	3.	4.	5.	6.
SiO_2	38.07	46.69	59.05	62.65	69.33	75.41
TiO_2	3.62	0.35	0.96	0.74	0.36	0.25
ZrO_2	—	—	0.01	0.03	0.01	0.03
Al_2O_3	17.17	18.51	16.64	16.13	17.05	13.21
Fe_2O_3	9.07	0.66	2.56	2.16	0.82	0.80
FeO	9.10	7.63	4.26	3.30	1.10	1.06
MnO	0.17	0.11	0.10	0.09	0.06	0.02
MgO	8.16	14.85	3.31	2.76	0.42	0.07
CaO	11.74	8.94	7.23	5.69	3.34	1.51
BaO	—	—	0.c9	0.05	0.05	0.c6
Na_2O	1.55	0.89	3.78	2.89	5.21	3.57
K_2O	0.34	0.52	1.77	3.11	1.66	4.11
P_2O_5	trace	non	0.33	0.15	trace	trace
F	—	—	—	0.20	—	—
H_2O +	0.76	0.61	0.26	0.18	0.86	0.11
H_2O —	0.08	0.09	0.04	0.11	0.05	0.03
	99.83	99.85	100.38	100.24	100.32	100.24

1. Ultrabasic gabbro, Isla Duntze, Canal Cockburn.
2. Olivinegabbro, Isla Duntze, Canal Cockburn.
3. Augite-hornblende-biotite diorite, Isla Nelson, Canal Brecknock.
4. Augite-biotite diorite, Isla Duntze, Canal Cockburn.
5. Plagioclase granite, Isla Londonderry.
6. Gneiss-granite, Ventisquero Jendegaia, Canal Beagle.

than the potassium, as analysis No 5 shows. In a similar, incomplete analysis, published by NORDENSKJÖLD (41, p. 191) $K_2O : Na_2O$ again is 2.59 : 4.39 the proportion consequently varies in a considerable degree. We find that both adamellitic granites and pure lime-sodium granites are represented.

Broadly speaking, the differentiation within the big mass of Andean dioritic rocks is not pronouncedly directed towards the lime-sodium pole or the potash-pole. Both types are represented. After all, the differentiation seems to represent a rather incomplete stage. There undoubtedly exists a strong tendency to split up into alkali-rich and lime-soda-rich components, but this splitting has been carried through only in a few places.

The most interesting case is that of the monzonites of Isla Navarino. The relation between these rocks and the components of the main-series appears from the table p. 222. It is obvious that in spite of the high silica-percentage the composition of the monzonite resembles more the basic components of

the main-series than the alkali-rich, acidic members. The high lime-percentage has already been pointed out, together with its probable explanation (p. 174). Above all, the percentage of accessory oxides P_2O_5 and MnO is remarkable as correspondence to the percentage in the basic members. Further, we have seen that the monzonites occur in the field intimately connected with gabbros.

We therefore have good reason to suppose that the monzonites derive from the basic part of the series and not from the acidic granitic part. This explains also the low silica-percentage in the syenitic rocks. As already shown, the basic qualities probably were increased through assimilation of lime-rich sediments.

The petrological investigation shows that the Andean diorites of Tierra del Fuego generally belong to the Pacific cycle of rocks with a slight Mediterranean tendency, more especially along the contacts of the rock-body. The character is mainly the same as in earlier investigated diorite areas in other parts of the American Cordillera, particularly the Coast range and Sierra Nevada. This resemblance appears very plainly on comparison with *e.g.* BUDDINGTON's compilation, in his interesting investigation of the Adirondack magmatic stem (15).

C. THE LOCAL DISTRIBUTION OF THE DIFFERENT ROCK-TYPES.

It now only remains to find an answer to the two questions on p. 153 about the local distribution of the rock-varieties. The observations available show no regular changes in composition between one part of the area and another, taken as a whole. The same local variations have been observed at almost all the places investigated, with the exception of the alkaline area of Rio Grandi. On the other hand, the composition of the rock-ground at every single point is very strongly differentiated, and comprises rock-types ranging from granites to basic gabbros. Broadly speaking, the rock-types are of more or less the same kind at every locality. — These facts prove that the composition of the magma at the intrusion was fairly homogenous, and that the differentiation was mainly *mise-en-place*. The processes of intrusion and differentiation will be discussed in another connection (p. 197).

The basic rocks have regularly crystallized earlier than the acid ones, and they are often found as inclusions in the latter.

A tendency to more general differentiation is indicated by the frequent occurrences of ultrabasic rocks along the border of the batholith, but on the other hand such rocks are also found in the inner parts of the area.

VI. THE GRANITES OF THE CENTRAL-CORDILLERA.

The granites of the Central-Cordillera have hitherto been but incompletely studied. They differ from the Andean diorites in being more or less influenced by the orogenic movements. Boulders found in the glaciers of the High-Cordillera are the main source of information about their distribution; only at a few places have they been studied in place.

The observations of the present author show that granitic rocks occur in the inner parts of Cordillera Darwin much more extensively than the earlier descriptions of Nordenskjöld, Quensel and Bonarelli have rendered probable. Granitic boulders are found not only below the glaciers of the south coast of Canal Beagle, but also in several places on the north side of the mountain chain, such as at Ventisquero Marinelli, in the innermost parts of Fjordo Finlandia and Fjordo Agostini, and so on. Though the contacts of these granitic rocks have been studied only at a few points, it seems very probable that the whole kernel-ridge of Cordillera Darwin consists of granitic rocks.

The degree of alteration in the samples hitherto studied is very different, and, as a matter of fact, there is no definite proof that they all derive from the same intrusion. It seems very probable that they belong to a series of intrusions occurring at longer or shorter intervals during the greater part of the folding of the Central-Cordillera. We have seen that the granites along Canal Beagle (Puerto Olla to Ventisquero Italia) are intruded later than the main-folding. On the other hand, the diorites of Valle Desillusion and the granites found in boulders in the neighbourhood of Ushuaia have participated in these movements. In the following it will be seen that, in spite of this obvious difference in time between the intrusion of the granites of the Central-Cordillera, they are petrologically closely connected and probably derive from a similar stem-magma.

In the following a number of specimens comprising the most important of the types hitherto known will be described.

C e r r o S v e a. The granite from this locality has been described by QUENSEL (45). It is interesting, owing to its position near the northern front of the Central-Cordillera, in another zone than the granites of Cordillera Darwin.

The granite of Cerro Svea is a coarse, medium-grained, light-gray rock consisting of quartz, orthoclase, plagioclase and biotite, with epidote, sillimannite, muscovite and chlorite as accessory components. The dominating felspar is an oligoclase albite. The structure is hypidiomorphic, with traces of tectonic alteration, which evidently has caused the crystallization of some of the last-named minerals. It is, however, not stronger than that the rock megascopically looks practically undeformed.

This is a rather strange fact, as the Cerro Svea granite occurs in a part of the Cordillera where the mylonitization of the rock-ground is strong, and as the Cordillera granites in general are more altered farther northward from the coast of Canal Beagle. The granites of Cerro Svea therefore in many respects correspond more to the Andean diorites, particularly the diorites of Isla Clarence, than to the more or less gneissic granites of the Central-Cordillera. QUENSEL has compared this occurrence with the Patagonian laccolites, though these probably are younger (Post-Cretaceous and decidedly Post-Kinematic).

T h e N o r t h C o a s t o f C a n a l B e a g l e. On the north coast of Canal Beagle, from Puerto Olla to Ventisquero Italia, a great number of different granitic and dioritic rocks are found. They are partly porphyric, partly even-medium-grained, generally showing more or less well developed parallel-structure. The latter is, however, not nearly so conspicuous as in the gneisses deriving from the inner parts of the Cordillera, and is sometimes hardly visible in hand-specimen (*cfr.* p. 85).

The following are the most important types:

Sp. 197. *Coarse porphyry-granite.* Ventisquero Darwin, Canal Beagle.

The rock is evidently the same as the granite described by QUENSEL from Canal Beagle (45). It is megascopically characterized by angular phenocrysts of white plagioclase 1—2 cm in size, with a matrix in which quartz and black seams of biotite are the dominating constituents.

The composition is plagioclase, quartz, biotite, muscovite, magnetite, epidote and apatite and, in very small quantities, K-felspar. The p l a g i o c l a s e - p h e n o c r y s t s are quite clear and show no signs of stress. Twinnings according to Carlsbad, pericline and albite laws. In the main part of the crystal the composition is 32 % An; in the outermost shell it is slightly more acid. The zonar-structure is less developed than in the undeformed Andean diorites.

The matrix is in some degree influenced by mechanical deformation. The quartz is crushed and undulated, and the biotite-seams are often bent. The last-named mineral is of a very dark, blackish-brown colour. K-felspar is rather sparsely present, mainly in the form of myrmekite, on the boundaries of the big plagioclase grains. The epidote, which plays a bigger role than in the foregoing rocks, is almost colourless, idiomorphic and clear. A number of small garnet-grains were also observed.

Sp. 202. *Porphyric granite* (Fig. 1, Pl. XXXII), of almost the same character, but which has suffered very much more by tectonic movements during the crystallization. It occurs near the Italia glacier on the east shore of the bay.

It shows also big, white phenocrysts of plagioclase, which megascopically seem to be fairly well preserved. The dark ground-mass is in contrast very strongly pinched out, and the biotite and chlorite seams bend like lenses around the big plagioclase individuals. The mineralogical composition is the same as in the foregoing rock, but the percentage of garnet and also of the other dark components is greater. The big phenocrysts show 26 % An. The plagioclase and the quartz are both completely crushed, and rolled out, or strongly undulating.

The biotite seams are orientated along the shear-planes of the rock, together with abundant epidote.

Sp. 194. *Coarse-medium-grained epidote-biotite diorite.* Puerto Olla (Fig. 1, Pl. XXXI).

Owing to the dominant rôle played by the epidote, this rock has a very interesting mineralogical composition. It differs megascopically in no respect from a common gray medium-grained biotite granite or diorite. Under the microscope the dominating dark components, however, appear to be epidote and mica. The composition of the rock is the following: plagioclase, quartz, biotite, muscovite, epidote and garnet. Green hornblende was observed only in a couple of small grains. The structure is hypidiomorphic, granular, with traces of parallel texture. The felspar grains are surrounded by granulated zones of quartz and femic minerals.

The plagioclase occurs as big idiomorphic crystals, with zonar-structure and beautiful twinnings. It contains 23—31 % An.

Muscovite and biotite mainly occur along moving zones. The latter constituent is often slightly altered into chlorite, sometimes also into hornblende.

The epidote occurs as sharply idiomorphic crystals. The mineral is for the most part colourless or light-grayish. The bi-refraction is comparatively low, indicating a clinozoisitic composition. There are also small spots of a yellowish-green pistazite of the same kind as the late-magmatic

epidote of the Andean diorite, with very high bi-refraction and strong absorption. The epidote here seems to replace hornblende and pyroxene and partly also plagioclase.

This is seen still more plainly on studying the chemical composition of the rock: (No 1, Table XV).

TABLE XV.

	1.	2.	Norm of 1.		
SiO_2	59.96	59.05	Qz.	14.94	
TiO_2	2.48	0.83	Or.	12.23	
Al_2O_3	17.25	16.64	Ab.	30.92	Sal. 82.55
Fe_2O_3	1.87	2.56	An.	24.46	
FeO	3.31	4.26	Di.	6.38	
MnO	0.12	0.10	Hy.	4.60	
MgO	2.14	3.31	Il.	4.71	Fem. 19.14
CaO	6.47	7.23	Mt.	2.78	
BaO	n.d.	—	Ap.	0.67	
Na_2O	3.68	3.78		101.69	
K_2O	2.06	1.77			
P_2O_5	0.22	0.33			
H_2O +	0.75	0.26			
H_2O —	0.05	0.04			
	100.36	100.29	II, 4, 3, 4; Tonalose.		

1. Epidote-biotite diorite. Puerto Olla, Canal Beagle. Anal. L. Lokka.
2. Augite-biotite diorite. Isla Duntze, Canal Cockburn » »

The composition is pronouncedly dioritic, and resembles the augite-biotite diorite earlier described from Isla Duntze (p. 155). This typical Andean diorite is shown in No 2, Table XV. The similarity is as a matter of fact so great that one can well speak of heteromorphism between the two rocks, in so far that the epidote in 1 at least partly replaces the augite and hornblende of 2.

It is therefore of interest to decide in which way the different minerals in the two rocks correspond to one another. This is in some degree possible by comparing the quantitative mineral-composition of the rocks, although the result is not exact, owing to the slight difference of the bulk. It will, however, be sufficient to solve the principal question.

The following table gives the mineralogical composition determined by geometrical analysis. The small amounts of hornblende and garnet have not been taken into account. They do not exceed 0.5 %.

	I. Isla Duntze	II. Puerto Olla
Quartz	9.4	13.0
Orthoclase	1.1	2.5
Plagioclase	55.5	49.0
Biotite	17.1	18.1
Muscovite	—	1.6
Augite	11.9	—
Hornblende	1.8	—
Epidote	—	14.4
Magnetite	2.3	—
Titanite	0.2	0.8
Apatite	0.7	0.6
	100.0	100.0

The percentage of biotite in both the rocks is about the same. The higher potassium-percentage in the epidote diorite is mainly contained in the muscovite, the higher iron-content in the augite diorite in the magnetite. Without any great error we can therefore draw the conclusion that the epidote in I replaces the augite and hornblende in II. Evidently, also anorthite has taken part in the origination of the last-named mineral. This appears clearly on comparing the anorthite-percentage in the rocks with that of the norm. In I the norm has 23.7 % An, while the measured content is 22.5 %. The result of the check consequently is rather good. In II the norm has 24.4 %, while the real content was 16 % An. In the first case the plagioclase was calculated at 40 % An, in accordance with the optical determination, in the second at 30 %. The latter figure may be slightly too high.

In the epidote-diorite 8 % anorthite has consequently entered into the epidote-molecule and a little SiO_2 has been set free and has resulted in a slightly higher quartz-percentage than in the augite-diorite.

This calculation does not assume that the rock is a normal igneous rock in other respects than with regard to the chemical composition. As will later be seen, it is very possible that the epidotization is secondary, and that the primary mineral really was hornblende or augite, while the epidote has the character of idioblastic crystals, formed contemporaneously with the epidote of the surrounding schists.

Ventisquera Jendegaia. The petrological character of the boulders found in the moraine of the big glacier of Jendegaia (at the end of the main valley) greatly resembles that of the rocks described from the north shore of Canal Beagle, and they obviously derive from the same metamorphic zone of the Cordillera. The composition is also here characterized by the paragenesis

epidote, garnet and varying quantities of hornblende. Already HYADES describes the first-named mineral from this locality (l.c.).

The following are the most interesting of many specimens collected, and form good examples of basic and acidic gneisses from the Monte Bowen-*massif*.

Sp. 169. *Epidote-garnet-hornblende gneiss.* (Fig. 2, Pl. XXX) Ventisquero Jendegaia. The rock has megascopically a gneissic aspect. It is dark-coloured, medium grained with well developed parallel-structure. Like many of the boulders from Jendegaia the rock might partly be of migmatitic origin and have possibly assimilated some of the schists which it penetrates. The structure indicates a strong deformation, though the shear-zones are completely healed and recrystallized; the mineral-components generally are clearly orientated according to the deformation movements (geregelte Kristallisation). Mylonitization is absent. The structure is shown on the microphotograph Fig. 5, Pl. XXIX. The mineralogical composition is mainly the same as in the gneisses of Puerto Olla, consisting of the following minerals: plagioclase, quartz, epidote, biotite, hornblende, garnet, muscovite, ilmenite, titanite, pyrite and apatite.

The dark components are mainly arranged along moving zones on the rock, which bend around the more resistant big plagioclase grains, and give the structure a lenticular character. The q u a r t z is strongly granulated, with undulose extinction. The p l a g i o c l a s e is generally clear and unaltered, in exceptional cases slightly saussuritized. The composition is unexpectedly basic, with well developed zonar structure. The outer zone is about 53 %, the innermost 65 % An. The grains are always rounded and the edges crushed and rubbed off at the deformation. However, this deformation acted purely mechanically and does not seem to have caused any chemical alterations of the mineral. The h o r n b l e n d e occurs as elongated crystals with sinuous, in some degree resorbed edges. The colour is grayish-green, the absorption is fairly strong. The edges sometimes show a more bluish colour. The absorption is the following: γ (grayish-green) $>$ β (yellowish-green) $>$ α (light-yellow), γ : c. 12°. The g a r n e t is sharply idiomorphic, the colour is light-reddish. The mineral is almost isotropic. In contact with the epidote the edges of the grains sometimes are slightly blunted. E p i d o t e occurs as big, well developed, idiomorphic crystals, forming one of the principal components of the rock. One can distinguish three different types of epidote, generally occurring together. The dominant type is the colourless one described in the foregoing. The bi-refraction was determined as 0.042, corresponding to an iron-epidote percentage of about 30 % (GOLDSCHLAG, 26). The second type is dark-brown with strong absorption, but very low bi-refraction. It

generally forms the kernel of the foregoing crystals. The third type is the general iron-rich yellowish pistazite with uneven, anomalous interference-colours. It is the last of the three varieties to crystallize. The dominating ore-mineral is ilmenite, which occurs as small elongated, prisma-like crystals.

The following specimen is an acidic granitic gneiss.

Sp. 171. *Gneiss*. Ventisquero Jendegaia. Fig. 2 p. XXXII shows the outer aspect of the rock. It is a typical Alpine gneiss, resembling the well known rocks of St. Gotthard, Arolla etc. It is medium-grained, with strong parallel-structure and the dark components parallel-orientated along shear-planes in the rock. The mineral-components are: plagioclase, microcline-perthite, quartz, muscovite, biotite, epidote and small quantities of garnet, sillimannite, and titanite. The femic components are strongly subordinated. The microstructure is granoblastic. The mineral-components are strongly granulated. Myrmekite is seen in great abundance on the boundary between plagioclase and potash-felspar. The orientation of the quartz seems to be the same as in the quartzites described from the south end of Fjordo Martinez (p. 53). The K-felspar is generally dull and in some degree altered into sericite. The plagioclase is always highly altered, and the grains form a fine-grained mixture of epidote, mica and sillimannite. The remaining felspar is an oligoclase.

The rock is of interest as being the most acidic granitic rock found in the Cordillera of Tierra del Fuego. An analysis therefore was made by Dr. Lokka, with the following result (N:o I, Table XXXI).

The mineralogical composition of the rock shows a very high percentage of silica, and small quantities of femic oxides. Particularly the extremely low magnesia-content is remarkable. It resembles in that respect several alaskitic granites. The close chemical relationship with the Andean diorite series has already been pointed out on page 183.

Among the boulders in the moraine of Jendegaia there are also several ultrabasic, hornblenditic rocks. They are of the same types as the dikes observed at Puerto Olla and might belong to the same intrusive series.

The most conspicuous feature of the rocks described above from the Monte Bowen group is the similar mineralogical composition, which is found in almost every specimen of the area, quite independent of the bulk-composition. Already these facts point to the mineral composition depending upon a similar stage of alteration, rather than an original identical magmatic crystallization, though the latter

TABLE XVI.

I.		Norm.		
SiO_2	75.41	Qz.	34.26	
TiO_2	0.25	Or.	24.46	
ZrO	0.03	Ab.	30.39	Sal. 93.84
Al_2O_3	13.21	An.	4.73	
Fe_2O_3	0.80	Di.	2.28	
FeO	1.06	Il.	0.46	Fem. 3.90
MnO	0.02	Mt.	1.16	
MgO	0.07		97.74	
CaO	1.51			
Na_2O	3.57			
K_2O	4.11			
P_2O_5	trace			
H_2O +	0.11			
H_2O —	0.03			
	100.15	I, 4, 2, 4; Lassenose.		

1. Gneiss. Ventisquero Jendegaia. N coast of Canal Beagle. Anal. L. LOKKA. BaO 0.06.

is at first sight very conceivable on account of the well preserved primary-structures of many of the rock-varieties.

Of particular interest is the mineral-combinatione epidote — anorthite-rich plagioclase, which is in sharp contrast to the parageneses of prasinitic rocks, spilitic rocks and so on. The anorthite seems here to be comparatively stable, together with epidote, which, however, does not prove that we meet here some kind of equilibrium between both these minerals. As the rock-description has clearly shown, the epidote can be regarded as a secondary product, formed at an alteration which is later than the crystallization of the anorthite, and evidently contemporaneous with the origination of the gneissic structure. It has in other words the character of an idioblastic mineral. The calculation on p. 190 further proves that it is n o t m a i n l y f o r m e d i n p l a c e o f a n o r t h i t e but r a t h e r i n p l a c e o f a d i o p s i d i c a u g i t e o r h o r n b l e n d e, and this will in some degree explain the relation to the plagioclase. The newcrystallization has mainly taken place along crush-zones rich in femic minerals, and has left the plagioclase more or less intact, this being always very resistant against mechanical stress. The mechanically less resistant lime-rich femic components are altered into epidote.

This is a good instance of the great stability of nonequilibrial paragenesis in rocks in which strong movements have occurred contemporaneously with

the crystallization. These have given rise to very varying physico-chemical conditions in different parts of the rocks, not only in the complex as a whole, but also between the different mineral grains in every specimen.

The hornblende-garnet-bearing varieties evidently correspond to the glaucophane-garnet-bearing schists described from the south part of Fjordo Martinez, though the amphibole here is less rich in hornblende and the deformation during the crystallization has not been so strong. Here the strongest movement (Durchbewegung) seems to have finished at least in part before the last stages of recrystallization, and the rolling out of the mineral-grains therefore is not so extreme. The garnet and possibly also the hornblende seem to be contact-minerals.

According to the above theory, the mineral-parageneses of the Monte Bowen gneisses have been caused by at least three different factors. 1. Primary crystallization in a granitic to dioritic magma. 2. Contact-reactions, caused partly by the Andean diorites, but mainly by reactions with later intruded granites of the same series. 3. Recrystallization, caused in connection with the shear-movements at the orogenic actions. The two last-named processes seem to have worked contemporaneously. Until the minerals, mainly the epidote, have been analysed, it is, however, too early to discuss more in detail the interesting polymetamorphic reactions which have taken place in this rock-group.

Ushuaia, Puerto Harberton. Strongly metamorphic gneisses from the eastern parts of the Cordillera have already been described by NORDENSKJÖLD, who found some samples in the moraine of the tracts around Ushuaia. The present author has found rocks of the same type as far eastward as at Puerto Harberton, as well as in all the valleys he visited east of Cordillera Darwin. They partly seem to derive from the last-named rock-*massif*, but it is also possible that also farther eastward there still exist unknown granite-occurrences of the same type as those at Valle Desillusion.

The rocks are generally strongly schistose and more deformed than the types described above. The mylonitization is generally conspicuous. The composition corresponds to that of the acidic granite from Jendegaia, with comparatively abundant KNa-felspar. The quartz-grains are rolled out, often into layerlike, thin lenses, with recrystallization ruled by the deformation and resembling that of Bahia Plüschow (p. 53). The plagioclase is

altered into a dull mass of epidote, mica and abundant sillimannite. The potash-felspar for the most part forms myrmekites, which grow into the quartz-grains.

In the more deformed rocks there is a strong tendency to separate the femic minerals — mica and epidote — from the colourless ones (Fig. 4, Pl. XXXI). The altered plagioclase-grains are completely crushed up. The mica and epidote are concentrated along shear-zones, between elongated grains of albite, quartz and sometimes potash-felspar. The rock has the aspect of an acidic quartzbanded gneiss.

The Western Parts of the Central-Cordillera.

The gneissic granites found in the western parts of the Cordillera are in general less deformed than the rocks of the eastern regions described above, and are in many cases difficult to distinguish from Andean diorites. They are generally hornblende-bearing rocks, containing both soda- and potash-felspar. From these sections the following types were investigated:

Sp. 35. *Gneiss-granite.* Boulder from Puerto Garibaldi.

The rock represents a very deformed type of the Cordillera granite, which resembles the rocks found as boulders in the surroundings of Ushuaia, etc. The mineral components are: quartz, plagioclase, K-felspar (perthite), biotite, muscovite, epidote, magnetite and garnet. The dark components are very subordinated.

The structure is granulated, most of the mineral-grains being crushed up. The K-felspar is perthitic and generally fairly unaltered, the plagioclase is filled with epidote-crystals. The epidote also occurs as bigger grains, partly with a dark-brown kernel.

Sp. 310. *Granite.* Boulder from the southern end of Fjordo Finlandia. (Fig. 3, Pl. XXXII).

This rock is petrologically a transitional form between the Cordillera-granites and the Andean diorites. The mechanical deformation is not conspicuous and the mineralogical composition resembles more that of a rock belonging to the first-named group, than that of the granites of the Central-Cordillera.

The abundance of these boulders in the moraines on the northern side of Cordillera Darwin shows that the rock occurs in that mountain-group.

The mineralogical composition is plagioclase, microcline (perthite) quartz, hornblende, titanite, zircon and magnetite. The structure is panallotriomorphic and in some degree granulated. The rock differs from the Andean diorites in the allotriomorphic character of the plagioclase crystals. Myrmekite is present in abundance.

The plagioclase is the dominating component. It is always of zonar-structure, with 36 % An in the inner parts of the grains, or almost the same as in the granites from East Beagle. The mineral is only slightly altered into sericite and epidote. Inclusions of an isotropic mineral, evidently a zeolite, are sometimes seen in the plagioclase.

The hornblende is of the common green or bluish-green type, occurring also in the Andean diorites. It occurs as rather irregularly shaped grains, often replaced by

epidote in the margins. The last-named mineral also occurs as independent grains. It is greenish-yellow pistazite, with strong bi-refraction and dispersion.

Sp. 317 is an almost white, coarse-grained acid granite, occurring as boulders at the southern end of Fjordo Martinez. The dominant part of the rock consists of plagioclase with 25 % An and quartz. The dark components are very few and unimportant, generally muscovite and epidote. Also K-felspar is fairly abundant.

The structure is eugranitic, with very slight indications of mechanical influence.

Of almost the same composition as the granite described above are the porphyry-granitic dikes which traverse the schist-formation around the southern-end of Fjordo Martinez. They are, however, always strongly stressed and granulated.

EXPLATION TO PLATE XXXI.

Fig. 1. Epidote-biotite diorite. Rounded, big plagioclase-crystals surrounded by more small-grained, granulated quartz and femic minerals, mainly epidote and biotite. The structure has obviously undergone a mechanical deformation. Puerto Olla, North coast of Canal Beagle. Magn. 13 ×, Nic. +.

Fig. 2. Detail of Fig. 1, showing the sharply idiomorphic epidote-crystals and biotite-grains. Magn. 22 ×, Nic. +.

Fig. 3. Gneiss with well developed, orientated crystallization. Ventisquero Jendegaia, Canal Beagle. Magn. 19 ×, Nic. +.

Fig. 4. Strongly deformed gneissic central granite with undulose, orientated quartz-grains. The potash-felspar is altered into epidote, muscovite and sillimanite. Boulder from the vicinity of Ushuaia. Magn. 12 ×, Nic. +.

Fig. 5. Epidote-garnet gneiss with hornblende, biotite, muscovite and basic plagioclase (to 60 % An). Boulder from Ventisquero Jendegaia, Canal Beagle. Magn. 12 ×, Nic. ||.

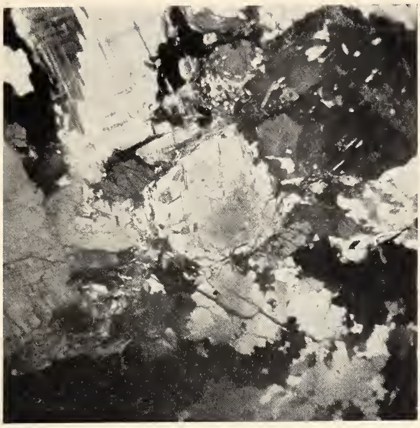
EXPLATION TO PLATE XXXII.

Fig. 1. Porphyric gneiss-granite with strongly deformed ground-mass. Ventisquero Italia, North coast of Canal Beagle. The big white phenocrysts consist of plagioclase.

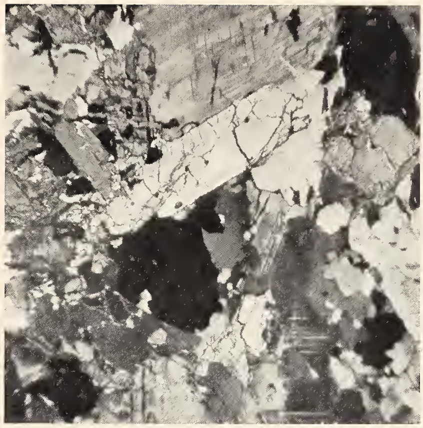
Fig. 2. Gneiss from the Central Cordillera. Boulder from Ventisquero Jendegaia. (The micro-structure is shown on Fig. 3 Pl. XXXI).

Fig. 3. Hornblende granodiorite from the Central-Cordillera. Boulder from Fjordo Finlandia, S of Seno Almirantazgo.

Fig. 4. Mylonitized and metamorphosed diorite from the eastern part of the Central Cordillera. South slope of Valle Desillusion near Cerro Quensel (*cfr.* p. 96).

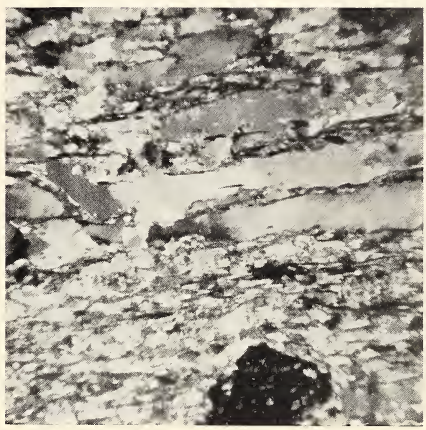


1



2

3

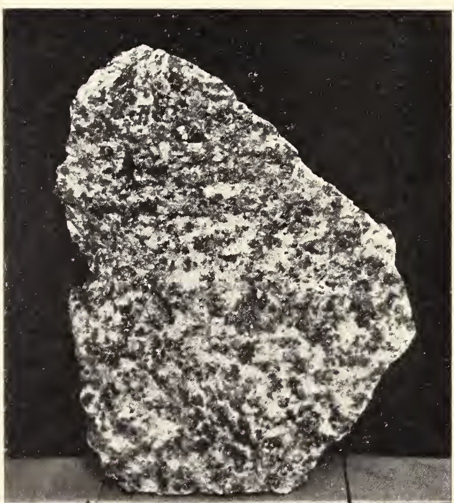


4

5

1

2



3

4

From the tracts farther north-west granitic rocks have been described from Isla Santa Ines (p. 142). These possibly in part belong to the Cordillera granites, and are in some degree older than the Andean diorites. So far it is uncertain whether this granite also occurs in the Patagonian Cordillera or not. The corresponding rocks of the Coast Cordillera are all described as Andean diorites, but there are actually types among them, *e.g.* the granite of Rio Aysen, which have a petrographical character resembling the last-named. Typical Central-Cordillera granites are possibly to be found in the inner ice-covered parts of the highland north of Ultima Esperanza, etc.

VII. THE RELATION OF THE ANDEAN DIORITES TO THE GRANITES OF THE CENTRAL-CORDILLERA AND THEIR INTRUSION-PROCESSES

The most striking difference between the two rock-groups named above is the different degree of alteration. The granites of the Central-Cordillera are to a considerable but very unequal extent affected by the orogenetic movements during the folding. With but few exceptions the Andean diorites lack traces of mechanical influence; they are decidedly post-kinematic. The foregoing descriptions make it obvious that there is a considerable interval of time between the intrusion of the last-named rock-group and the older granites of the Central-Cordillera. On the other hand, they both undoubtedly belong to the same orogenic cycle; there has not been any lengthy period of erosion between their intrusion. The Cordillera-granites probably comprise rocks of rather different age.

From a chemical point of view the Cordillera-granites generally are more rich in silica and potash-felspar, but can after all only in a few cases be regarded as potash-granites. As a rule, the composition also here more resembles the diorites, containing more sodium than potassium. The close relationship of the rock-groups is clearly shown by the variation-diagrams p. 183. They could without difficulty be regarded as deriving from the same stem-magma.

The infracrustal granito-dioritic intrusion in the Fuegian Cordillera begins with acidic granites, during an early stage of the folding. It continues until the later stages of the main-folding. Afterwards more basic dioritic magmas intrude, and partly split up into acidic and basic components. The sequence is consequently in some degree the same as that which Backlund has described from the Andes of southern Mendoza (6, 7) and which W. Penck from Puna de Atacama has associated with the Andine tectonic cycle. The connection with the orogenic development of the mountain-range here evidently must be explained in a somewhat different way, the series comprising only a minor part of the development of the mountain-range (*cfr.* p. 215).

The intrusion of the deepseated rocks of Tierra del Fuego probably was a more or less continuous process, though the course of intrusion changed to some extent, owing to the development of the orogenic movement. The earliest granitic intrusions partly had an ophiolitoid character.

The action of intrusion of the Andean diorites was less disturbed by orogenic movements, as the undeformed aspects of the rocks clearly prove. The investigation of this action has to take into account the following circumstances dealt with in the foregoing:

1. The recurrence of more or less the same rock-types all over the area.

2. The incomplete separation of the femic and salic parts of the magma-mass and the frequent occurrence of eruptive breccias.

3. The considerable difference in structure in different parts of the magma-body.

As already pointed out, the magma at the intrusion probably was fairly homogenous. If this assumption holds good, the above-named circumstances clearly prove that the intrusion cannot have been a single process. The rock-mass cannot possibly have intruded all at once and have crystallized out of a single magma-mass.

Rather must we suppose that the intrusion took place gradually, and during a very long period of time. Probably most of the rocks never have existed in a molten state at one and the same time, in their present positions within the big igneous rock-body.

The intrusion took place in connection with a gradual, very slow opening of the reservoirs in the earthcrust in which the magmas were pushed in. The opening in many cases was only slightly more rapid than the process of crystallization. It was mainly caused by the last forces of the orogenic action (*plis de fond*, ARGAND, 5), partly by the hydrostatic pressure of the magma. The earlier intruded masses were already to some extent completely cooled and differentiated through fractional crystallization when the later portions came trough.

Such an interpretation of the process of intrusion explains in a natural way the irregularities within magma-masses of the same type as the Andean diorite area.

The occurrence of the Andean diorites as an elongated area along the back-border of the Cordillera has a striking resemblance to the row of young tertiary intrusions along the south-border of the Alps; the Val Cérvo intrusion, the Monte Matterone laccolite, the Bergeller-*massif* and the Adamello-*massif*, and as we have seen also the petrological character of the rocks is partly very

similar. The post-orogenic intrusions in the southernmost Cordillera of South America only differ by forming a single, coherent area, which, however, may in part depend on the deeper erosion. As has already several times been pointed out, occurrences of the same type can be shown also from other mountain-chains, such as in the Caledonides, the Hercynides etc. A more detailed discussion will not be entered upon here, as the scarcity of the observations hardly warrants this.

The intrusion of the granites of the Central-Cordillera mainly took place in connection with strong movements in the surrounding rock-masses. These rocks differ mainly from the rocks described above in that, in the former case, the forces which caused the intrusions only opened the intrusion-channels, while, on the other hand, the forces which caused the intrusion of the Cordillera-granites afterwards again tried to close the openings, and in that way caused a deformation of the rock-masses already crystallized. This deformation in many cases probably is very much younger than the *mise en place.*

VIII. THE STRATIGRAPHY OF THE CORDILLERA OF TIERRA DEL FUEGO.

Already DARWIN divided the sediments of the Central Cordillera into two groups, the first comprising the high-metamorphic schists along the western part of Canal Beagle, the second comprising mainly the dark phyllitic schists around the east part of Canal Beagle and in the southern archipelago, of which the last-named were referred to the clay-slate formation. As already has been pointed out, this division has been modified in different ways by later investigators, and more especially the clay-slate formation has been shown to comprise sediments of different geological systems (Jura, Devon, Cretaceous). Seeing that up to the present we have no observations which would definitely settle the exact age of the last-named formation of the Central-Cordillera of Tierra del Fuego, the present author has used the term »Yahgan formation» as a neutral local designation for the less metamorphic dark slates and related rocks of the south-eastern part of this region. Very similar rocks were also found on the inside, *i.e.* the north side, of the central schists on Peninsula Buckland and Seno Almirantazgo. At the first-named locality they were called the Buckland series and evidently belong to the same formation. The most important stratigraphical problem of the whole of the Central-Cordillera is the relation between these two formations and the high-metamorphic central schists. A comparison of the structure and composition will in some degree throw light on this question.

The high-metamorphic central schists are for the most part composed of quartz-rich mica schists and quartzitic schists. The general type greatly resembles the rocks of the Central Alps in the kernel parts of the great nappes of the Penninicum (Casanna schists etc.) though the schists of Tierra del Fuego rarely are so strongly recrystallized as the most altered Pennine schists. Pure lime-sediments are almost entirely absent in Cordillera Darwin etc. These circumstances, in addition to the abundance of quartzitic rocks, point to the deposition in shallow water of at least a great part of these sediments.

However, there is also an abundance of strongly sheared carbon-rich sediments, and also micaceous schists containing calcite (lime-phyllites), which might have a position corresponding to the so called *schist lustré* of the Alps (ex. Lapataia, Valle Desillusion).

An interesting feature, which must be regarded as a typical Alpine formation, is the occurrence of the ophiolitic greenstones. These represent a rock-type belonging to the great geosynclinal foldings, and afford good evidence that we here actually have to do with tangential movements of the said kind. As far as the present author knows, ophiolites have not earlier been described from the southern parts of the Cordillera of South-America, Steinmann (56) on the contrary stating that the lack of ophiolites and radiolarites is one of the most typical features of the Andes, in contrast to the mountain-ranges of Europe and Asia. This has in part been regarded as evidence that there is in the Andes no geoynclinal sedimentation proper.

The present author has in the foregoing tried to make it evident that this assumption does not hold good in the southernmost part of the Cordillera, that we here have a typical geosynclinal sedimentation, and that the folding has occurred in connection with big tangential movements. On the other hand, as will be proved later, this sedimentation is as regards age not comparable with the so called Andine-stage of the Cordillera-folding.

The present mineral-composition, and in most cases also the comparatively coarse crystalline aspect, depends, according to the present author, mainly on the intense deformation and contemporaneous recrystallization. The contact-influence, due to the intruding granites, has played a role in certain sectors, but is not the main factor as regards the strong recrystallization, as several geologists have supposed (Quensel, Bonarelli).

The dominating part of the rocks of the Yahgan and Buckland formations generally consists of rather fine-grained dark sediments of phyllitic aspect, comprising common argillite, phtanite, marl-schists and graywackes. The beautiful layering and the petrographic character of the rocks show that they have been deposited in water, and obviously not quite close to the coast. The marine origin is, however, definitely proved by the occurrence of micro-fossils in great abundance throughout the area.

As was shown in the foregoing, these fossils are radiolarias and globigerinas of probably different kinds (p. 149).

Also the Yahgan formation contains ophiolitic greenstones, as well as acidic eruptive rocks. Of the last-named the quartz-porphyries of Almirantazgo and Azopardo are particularly important.

While the tectonic conditions in the metamorphic schists of Cordillera Darwin are too complicated to allow of any stratigraphical subdivision or a determination of the stratigraphic sequence within the formation, the two later groups in some degree show the original position of the sediments. Before entering upon this question it is necessary to study the contact conditions with the high-metamorphic schists of Cordillera Darwin.

The profile of Monte Buckland affords the best opportunity observed by the present author. Here the sediments of the Buckland series rest directly on the underlying schists, obviously in primary position. The contact layer consists of a breccia or conglomerate, which, in spite of considerable mylonitization, does not appear to prove that any big overthrusts have occurred at this place. The lower layers of the Buckland series consist of quartz-porphyries and tuffs of the same type as those occurring at Azopardo. They are interbedded with radiolaritic schists and grade upwards in fossiliferous argillites of types similar to the rock from Canal Beagle.

At Fjordo Finlandia conditions are more complicated. Here the porphyries of the bottom-layers of the formations are infolded and overridden by the high-metamorphic central schists, and are in part themselves highly metamorphic, of about the same aspect as the last-named (p. 81). Evidently, the stratigraphic sequence has undergone conversion here. Also on the south-coast of Seno Almirantazgo the porphyries seem to be overthrust and pushed forward towards the sediments of the Marginal-Cordillera. At la Paciencia they rest on radiolaritic sediments, which are comparatively undeformed, in contrast to the undermost layers of the porphyry series, which are strongly mylonitized.

In these occurrences the quartz-porphyries consequently seem to lie between the high-metamorphic schists and the slaty schists. This position was already assumed by BONARELLI (11, p. 64) who, however, seems to refer the porphyries to a younger horizon than the fossiliferous schists, an assumption which evidently is erroneous.

The observations cited in this paper prove that the quartz-porphyries belong to the Buckland-series and that there evidently exists a discordance between these rocks and the high-metamorphic schists of Cordillera Darwin. According to the present author the porphyries form the lowest horizon of the

Buckland-series. The interbedding with radiolaritic schists clearly indicates a submarine eruption of the porphyries.

On the south coast of Tierra de Fuego conditions seem to be in many respects similar. The sharp difference between the rock-ground on both coasts of Canal Beagle, from Lapataia westward, points also here to a discordance, though the contact has not been studied in detail. At several places along the channel one finds ocurrences of mylonitic quartz-porphyries, all situated within the Yaghan formation. Very enlightening is the occurrence at Monte Olivia, which lies between dark slates, containing remains of radiolarias. Here the porphyries in other words do not lie right on the contact, but are partly interstratified between argillitic and phtanitic schists, in similarity with the Azopardo-porphyries.

The Yahgan formation, inclusive of the Buckland-series, is folded together with the Central-schists, and it is therefore difficult to decide if any foldings of importance occurred before the stratification, or if the different degrees of deformation depend mainly on local tectonic circumstances. The latter certainly is the case along the northern border of the mountain range.

The slates of the southern archipelago have been subdivided more in detail by Bonarelli (11). His division comprises an upper and lower group of »the roof of the Andean dioritic batholite» on Isla Navarino and Hoste, and separate from these a third goup of palaeozoic schists, formed by the tracts north of East Beagle. This division seems mainly to be a theoretical one, carried out according to the scanty data available in the older literature. A consequence of the incomplete data is that his map in many points gives an erroneous picture of the geology of the tracts in question. Owing to the different degree of alteration, Bonarelli refers the schists on both sides of East Beagle (*e.g.* at Ushuaia) to different formations. As we have seen, such a division is not possible according to the recent observations, which give similar schists on both sides, though those on the north side are more altered, owing to the stronger tectonical deformation. Both,. however, contain similar radiolarites and also graywackes of a corresponding type. — The description by Bonarelli gives the impression that the sediments on Navarino, and particularly along its north shore, are more metamorphic than those on the north side of Canal Beagle. This is, however, an obvious mistake; conditions as a matter of fact being quite the opposite. Evidently, he has been misled by the erroneous conception that the crystalline structure of the central schists is mainly due to the contact metamorphosis — therefore all the metamorphic central schists and also the schists of the southern archipelago have been included under the heading »*El techo del batolito*». — In consequence of the

occurrence of Andean diorite on the north shore of Navarino, reported by LOVISATO (cfr. HYADES, 32), BONARELLI has drawn the conclusion that the schists must be of the same character as those of Cordillera Darwin. The map shows the same mistake also in other parts of Tierra del Fuego.

A more detailed stratigraphic division of the Yahgan formation is as yet impossible, until we get more data about the tectonic and the stratigraphical position of the different strata from different parts of the area, but it is of course very probable that it contains sediments deposited at different times. One observation pointing to this may be cited here.

In the foregoing we have seen that an important series of argillitic schists and phtanites is closely connected with the quartz-porphyry formation — the basal formation — and frequently contains crystal tuffs and felsitic tuffs. On the other hand, we have seen that graywackes play an important rôle particularly on Isla Navarino and Peninsula Dumas. These graywackes contain an abundance of small volcanic fragments, which always consist of basic volcanic material (propylitic?) but are never quartz-porphyric. They may, in other words, belong to quite another sequence of volcanic activity than the porphyries. This activity was probably younger. The facies of the sediment also points to deposition in shallower water nearer to the shore.

The fossil fauna contained in these two series is also in some degree different. Only simple ovoidal fragments of radiolarias have been found in the phtanites, sometimes with some single outgrowth, though rarely with preserved concentric structure. In the graywackes we find comparatively well preserved centrically indented rings around the radiolarias, which seem to have a more complicated shell than in the foregoing group (*cfr.* Figs. 3 and 4. Pl. XXV). In addition, remains of globigerinas are fairly abundant, and have been described already by HYADES and NORDENSKJÖLD (Ushuaia, Canal Murray).

Rocks belonging to the former series have been found on the north side of the Cordillera at Monte Buckland, Puerto Tristeza, and Seno Almirantazgo; on the south side at Puerto Toro, Rio Douglas, Ushuaia, Monte Olivia and some other points. Rocks belonging to the latter series have been found more especially at Rio Douglas, Puerto Toro, beyond Pike Navarino, Peninsula Ushuaia (south coast) and Canal Murray. Locally the formations are consequently not sharply separated, and the discordance between them was therefore probably not big. Most likely it had the character of an overlapping of littoral and bathyal-sedimentation.

The observations are too scarce to allow of any definite division of the Yahgan formation, but at least the following rock-groups can, however, with great probability be distinguished.

1. Fossiliferous graywackes and argillites usually comparatively rich in carbonate.
2. Fossiliferous phtanites and argillites.
3. Quartz-porphyries and corresponding tuffitic rocks partly interstratified with fossiliferous schists.

Between 1. und 2. there was probably intense volcanic activity, traces of which remain in the propylites of Isla Hoste and the andesitic rocks of Rio Douglas on Navarino.

The sediments of B a h i a T e k e n i k a, known from the fossil-descriptions by HALLE (30) are of very varying aspect. According to the latter, these sediments are Jurassic and it has been suggested (HALLE, 30, QUENSEL 45.) that also the other sediments from the southern archipelago described above are of the same age. This seems, however, hardly likely to have been the case. Already the type of sediments points to very different conditions at stratification. The Tekenika sediments are mostly continental and contain plant-fossils and a fauna indicating shore-sedimentation. The latter are typical marine-sediments. The lithological character of the former actually in every respect corresponds to the Cretaceous »Flüsch»-sediments of the Marginal Cordillera. BONARELLI (11) therefore seems to be quite justified in referring the graywackes and slates of Tekenika to the same Jurasso-Cretaceous formation as the sediments of Peninsula Brunswick, Isla Dawson etc., though it is of course necessary to gather still more observations, and above all have the fossil-fauna of Tekenika determined, before the question can be settled. The present author, however, believes that the Tekenika series is of much smaller extension than BONARELLI indicates on his map. At least, the localities he visited at Canal Beagle, marked as *Serie jurasico cretacico,* most certainly belong to the old Yahgan-formation.

The exact age of the Yaghan-formations is as yet difficult to determine. HYADES supposed that they may be as old as Carbonic or Permian, and to judge from the general character of the radiolarites this sounds very probable (*l.c.p.* 130). Already in another connection the great similarity with Devonian radiolarites from Central Europe has been pointed out. In every case they are very much older than the latest orogenic movements of the Cordillera of Tierra del Fuego, and may be Palaeozoic.

In some degree a comparison with the stratigraphical conditions of the older, Mesozoic sediments farther north in the Andes will throw light on the questions concerning the age of the schist-formation.

The quartz-porphyries of Tierra del Fuego have been parallelized with the porphyries and porphyrites in San Juan, Mendoza, Neuquen, etc., occurring

in the weastern part of the Andes, disconformably overlain by Liassic sandstones (WINDHAUSEN, 64). They seem to be partly symmagmatic with granites intruded in connection with the folding-facies of Malm (Cordillera del Viento, BACKLUND, 6). The underlying rocks are assigned to the Permian or Permo-Triassic formation. The disconformity between these formations and the Jurassic sediments evidently corresponds to the disconformity between the Cretaceous »Flüsch»-sediments of the Marginal-Cordillera and that of the schists of the Central-Cordillera of Tierra del Fuego. The correlation will be dealt with later on, in connection with the tectonics of the Cordillera.

The following table gives a review of the probable stratigraphic relations of the sediments of Tierra del Fuego and their relation to the eruptive rocks of the mountain-ridge. The age determinations are merely approximate.

	Sediments.	Igneous rocks.
The pampa of NE-T.d.F.	Magallanean beds (Tertiary).	Tertiary plateau-basalts and tuffs.
E parts of Pen. Brunswick and Isla Grande, Isla Dawson. Tekenika, Hoste.	»Flüsch»-sandstones, clay-slates, marls and conglomerates (Cretaceous). Sandstone and plant-bearing argillitic schists (Jurassic).	Melaphyres of Islas Carlos. (Laccolites of S Patagonia). Andesitic and basaltic lavas, (propylites).
The tracts around E Beagle, Isla Navarino. Isla Navarino, Hoste and N coast of E Beagle, Seno Almirantazgo, Pen. Buckland.	Yahgan formation / Mt. Buckland form.: Graywackes, marl-schists, argillitic schists (Triassic). Argillitic schists, phtanites, tuffites. Quartz-porphyry-tuffs (Permian).	Andean diorites Cordillera-granites. Andesitic and basaltic lavas (propylites of the older series). Ophiolitic greenstones. Quartz-porphyries of Azopardo, Beagle etc.
Cordillera Darwin, Cord. Ibanez, Cord. Sarmiento, Isla Clarence etc.	Micaceous schists, quartzitic schists, agglomeratic schists, etc. (The high-metamorphic central-schists). (Permo-Carbon, Devonian).	Old effusives.

IX. THE TECTONICS OF THE CORDILLERA OF TIERRA DEL FUEGO.

The data available concerning the geology of the Cordillera of Tierra del Fuego are still too sparse to permit a construction of the structure of the mountain ridge in detail, but they are in every case sufficient to give some of the main features of the tectonics, and point out the direction to be taken by future investigations.

Earlier geological researches in the Magallanes territories give hardly any data at all about the structure of the Cordillera, apart from the general information about folded sediments in the mountain ridge. BONARELLI gives in his paper a short summary of the tectonics, and states that the folding was mainly directed toward the north and north-west.

For original notes of more general interest we have to go back to the investigations of DARWIN, from whom almost all data about the tectonics derive. He gives some interesting data about the structure of the southernmost part of the mountain-range in especial. He pointed out the south-westerly turn of the Andes south of the Strait of Magallanes, and stated that the main-folding-zone follows the south-coast of the Main-Island of Tierra del Fuego over Strait la Maire to Staten Island. He quite correctly determined the strike of the folding axis in the western parts of the region as east-south-east — west-south-west and farther east as east-west. He also observed that owing to the changing direction of folding, the strike of the shore-lines generally does not exactly coincide with the direction of the folding axis, though there generally exists a connection between the two. The last-named fact was probably first mentioned by KING (36).

DARWIN also points out the tectonical similarities between the high mountains south of Seno Almirantazgo (Peninsula Buckland) and Cap Froward on Peninsula Brunswick.

Later investigators, HYADES, QUENSEL, FELSCH, etc. have mainly carried out petrological and palaeontological work and had no opportunities to give any data of importance about the tectonics. They merely state that the Cor-

dillera of Tierra del Fuego differs greatly from the Andes farther north, being a folding-chain already at Rio Aysen, while the latter mainly form a volcanic chain.

The foregoing descriptions show that the structural main elements of the Cordillera, mentioned on page 207, are characterized by the following style of folding and deformation.

The Yahgan-formation of the south-eastern part of the Cordillera forms tectonically a comparatively well defined section. The sediments are generally strongly folded, but not in a very high degree metamorphosed. In the mountains on the north coast of East Beagle, Montes Martial, Monte Sorondo, Monte Olivia, etc., the folds are generally simple and only slightly inclined. At Ushuaia the folding-plane is almost vertical, northward there is seen a northerly overfolding, and contemporaneously the intensity of the deformation increases. Fig. 44 and 53 shows schematically the general style of these tracts. North of Monte Olivia we enter a strongly mylonitized zone, which seems to indicate an overthrust-zone, pointing to the fact that the sediments of Monte Olivia and Cinco Hermanos are in some degree allocthonous, and pushed over the frontal sediments and the comparatively well preserved greenstones of Monte Carabajal.

South of Canal Beagle the sediments of Isla Navarino are considerably less deformed and more gently folded than on the north side. The folding is very weak, particularly along the north shore of the channel. Slightly more deformed rocks occur in the zone occupied by the high ridge along the north-coast of the island, and continue to Peninsula Dumas (Montes Sampaios). The primary structure of the rock is often almost unaltered also where the strata have a steep position.

Westward the folding again becomes more intense on the north part of Isla Hoste and Isla Gordon. However, the style is broadly speaking the same. The sediments here seem to be autocthonous.

The folding of the Yahgan-formation has evidently taken place at comparatively low pressure at high level. The deformation and mechanical alteration has to a considerable extent acted only along limited zones of shear movements (»Schuppenüberschiebung», »Blocküberschiebung» etc.).

The high-metamorphic schists of the Central-Cordillera have an Alpine nappe-tectonic with tangential-movements of several miles. In the central and front parts of the area the position of the schistosity is more or less horizontal, in the outer (S) parts it is generally steeper. Sometimes the schists are contorted against the foreland (Fjordo De Agostini). The root-zone of the nappes seems to be situated in the tracts

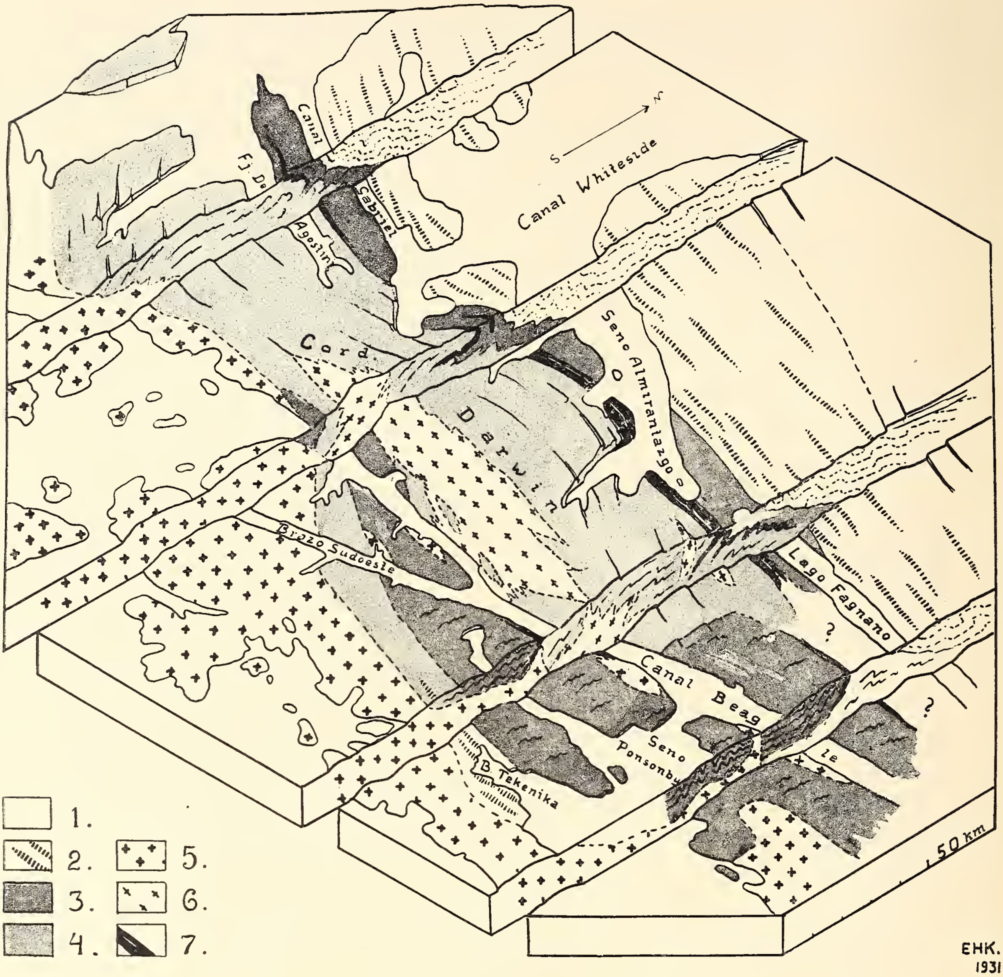


Fig. 59. Attempt to tectonic analysis of the central parts of the Cordillera of Tierra del Fuego

1. Tertiary »Molass» (Magallanean beds).
2. Cretaceous »Flüsch» of the Marginal Cordillera.
3. The Yahgan and Monte Buckland Formations.
4. The high-metamorphic schists of the Central-Cordillera.
5. Andean diorite.
6. Central granite.
7. Quartz porphyries.

north of the South-West-Arm of Canal Beagle and the sector south of Fjordo Martinez. The nappes have generally moved from south to north or south-west to north-east.

The rocks of the nappe-zones have been strongly altered owing to the internal movement. The central — and particularly the frontalparts and upper strata of the nappes — are strongly mylonitized (Lapataia, Fjordo Finlandia, Seno Staples).

The central schists mostly form a regular arch with the main-direction south-west—north-west. Particularly the front — the south-east border — shows some exception to this rule. At Seno Almirantazgo the margin of the central schists bends forwards, and from the vicinity of Bahia Brokes it again turns southward and then bends around the southernmost end of Isla Dawson. From here farther northward the front is more north-southerly; *i.e.* the folding is rather west-easterly. Evidently, a more resistant foreland existed in front of the last-named arch (38).

The Monte Buckland formation along the Cordillera-front corresponds stratigraphically to the Yahgan-sediments, but has slightly different tectonics. The strata are more deformed and have been influenced by stronger movements. They are always thrust forward towards the foreland sediments. At Fjordo Finlandia and Seno Almirantazgo the Buckland series are overridden by the central schists. On the north coast of Fjordo Finlandia (Monte Buckland) they rest on the high-metamorphic schists. Here they have evidently only been pushed towards the resistant foreland, forming the high mountains Buckland, Sella, Biella etc. (*cfr.* the stereogram p. 210).

In the southern parts of the Cordillera the nappe-structure becomes visible in an easterly direction in the tracts between Ushuaia and Lapataia. Farther north it stretches south of Lago Fagnano, and comprises the whole of the central part of the ridge up to Canal Magdalena. The same structure is also visible on Isla Clarence. The tectonical conditions of Peninsula Brunswick are not known, but at a landing at Puerto Gallant the author ascertained that we here also have the same old, overthrust schists as in Cordillera Darwin. At Cap Froward the slates (Buckland series?) are thrust towards the »Flüsch»-sediments of the Marginal Cordillera, in flatlying drawn out folds (Fig. 9).

T h e l o n g i t u d i n a l p r o f i l e o f t h e C o r d i l l e r a can as yet be drawn up only approximately, owing to the very few determinations of the axial-dip available.

In the easternmost parts of the Main-Island the folding-axis generally slopes gently eastward. This is seen already in some degree from the relief

of the country. The same direction is still found at Lapataia and Jendegaia, showing that the high-metamorphic schists of these localities dive eastward underneath the sediments of the Yahgan-formation. In the tracts west of Cordillera Darwin the axis slopes in a westerly direction, which means that we have an axial culmination in the highest part of the mountains of Tierra del Fuego (The Culmination of Cordillera Darwin). The westerly dip is found in the mountains of Cordillera Ibanez and Cordillera Sarmiento, where it is visible in the topography as steep west slopes and the more gentle east slopes of the cross-valleys. Also on Isla Clarence the same dip still seems to predominate.

The scattered observations which the author had opportunities of making farther to the west all indicate an axial-slope towards the south-east, and it therefore seems probable that the folding-axis of the southern Cordillera, taken as a whole, rises slowly in that direction. This means that the mountain-chain northward will be more deeply eroded, and as a matter of fact granitic rocks here play a much more dominating role than in the Cordillera farther south, while the sedimentary zone again is much narrower.

We can also draw the conclusion that the southernmost end of the South-American Cordillera finishes in an axial slope towards the Atlantic Ocean. On account hereof the mountain-chain gradually dives under sea-level.

As shown in the foregoing, the main axis of the folding of the Cordillera of Tierra del Fuego follows the south-coast of Isla Grande and continues on Islas Estados. This seems to hold good as regards both the folding of the old geosynclinal schists of the Central-Cordillera and of the epicontinental »Flüsch»-deposits of the Marginal-Cordillera.

A southerly virgation runs over Isla Gordon and Isla Hoste in the direction south-east towards Cape Horn. It is, however, less folded than the main ridge, and one is therefore hardly justified in calling this branch the main ridge, as R. Staub has shown in his analyses of the mountain-folding zones of the earth (53).

Owing to the occurrence of folded Jurassic schists at Tekenika, the age of the Cordillera-folding of Tierra del Fuego is generally interpreted as post-Jurassic.

This interpretation holds good with regard to the folding of the »Flüsch»-sediments of the Foreland (and Hinterland), which was Late-Cretaceous or pre-Tertiary, and consequently coincides with the Laramic folding of North America and the Andean cycle of South America.

Regarding the main folding of the geosynclinal sediments, which may be called the Fuegian folding, only the upper limit of the age is approximately known. We only can say that it probably was pre-Jurassic; the first paroxysms may have begun already in Permian times, when the old quartz-porphyries were intruded. This would correspond to about the Nevadian stage of the North American Cordillera.

A comparison with the tectonical and stratigraphical conditions of the Andes farther north in South America shows several similarities, which in some degree make a correlation possible.

At a great number of localities along the eastern border of the Cordillera (Neuquen, Mendoza, San Juan etc.) a great discordance has been observed between Permo-Triassic formations and Lias, evidently corresponding to that between the Central schists and the Cretaceous sediments on Tierra del Fuego. In the northern Andes generally only the younger of these series has been referred to the Andean geosyncline sedimentation, which consequently first begins with Lias (JAWORSKI, GERTH etc. 34, 24, 25).

According to existing descriptions, the basal formation of this stage of sedimentation is very similar to the Central schists of Tierra del Fuego. Near the boundary between the overlying Jurassic sediments quartz-porphyries are generally found grading westward into granitic rocks (Cordillera del Viento). These may be identical with the porphyries and porphyroides of Tierra del Fuego and Southern Patagonia (WINDHAUSEN 1921, 64). The folding of the old basal-sediments has been referred to an older mountain-folding, which generally had a more or less south-easterly strike, and according to GROEBER (27), WINDHAUSEN (64, 65) etc. formed an independent mountain-ridge (the Patagonides), which later has been covered by the sediments of the Andean geosyncline.

WINDHAUSEN has tried to connect the quartz-porphyries of Azopardo and South Patagonia with the same rock-group of the eastern coast of Patagonia at Puerto Deseado etc. and refers them to Permian (64). According to him the trend of the folding-zone of the Patagonides should in Tierra del Fuego and South Patagonia follow the Andine folding. On his map (64) the main axis runs north of the Central-Cordillera of Tierra del Fuego, *i.e.* through the bend occupied by the Cretaceous sediments of the Marginal-Cordillera.

According to the data given in the foregoing pages, such an interpretation is difficult to combine with the field-observations, which prove that the folding of the Marginal-Cordillera was Late-Cretaceous and further that there is a big discordance between the »Flüsch»-sediments and the quartz-porphyries

which belong to the same formation as the dark slaty schists etc. of the Yahgan- and Buckland-formations. If the old folding-facies of the Patagonides exists on Tierra del Fuego it would rather coincide with the main folding, the Fuegian folding, occupying the southern parts of the Cordillera.

According to a recent paper of WINDHAUSEN (66) the Patagonides are characterized by a folding style resembling that of the Alps, with overthrusts and nappes, *i.e.* the same style which in the foregoing has been described from the Central-Cordillera of Tierra del Fuego. On the other hand, the folding of the Marginal-Cordillera is comparatively simple, resembling the Jura-folding-style. The sedimentation was here a littoral or bathyal-sedimentation of epicontinental character.

After all, it is still too early to make any definite correlation of the Fuegian folding before exact fossil-determinations from the central-schists (Yahgan formation) have been made.

The principal difference between the Cordillera of Tierra del Fuego and the Andes of northern Argentina and Chile seems to be that the old pre-Jurassic sediments on Tierra del Fuego play a very much more important rôle within the Main-Cordillera; this being the case both as to their geographical extension and as to formation of the topography. This circumstance explains the great difference in tectonic structure between the southernmost Cordillera and the northern parts of the Andes. The strong geosynclinal folding of Alpine type seems to be restricted to the old Jurassic phase of the mountain range, which farther north is covered by the sediments of the Jurassic Sea and therefore has attracted very little attention.

The more predominating rôle of the old folding in the south may depend upon the southernmost Central-Cordillera having been lifted up very early, thereby having avoided a younger sedimentation. There is also the possibility that it was on the contrary lifted up and eroded comparatively late and the old kernel-formations laid bare in a higher degree than the rest of the Andes. The latter explanation is more probable.

By moving northward in the Andes we evidently find younger and younger movements forming the topographically dominating parts of the mountain-ridge. According to QUENSEL (45) we already at Rio Aysen find only a very narrow strip of metamorphic schists. Here they seem to be almost completely covered by the Jura-Cretaceous sediments. Contemporaneously,

the tangential movements become less important in comparison with the vertical movements.

An important question is whether the two phases of folding on Tierra del Fuego really have to be referred to different orogenic cycles, or if they can both be reckoned to the same mountain-folding. As has been shown above, there actually was a distinct, comparatively long hiatus between the two phases of folding, but the folding region on the other hand was the same, though the Andean stage was restricted mainly to the marginal-regions and had the character of a pre-Cordillera-folding. According to this point of view there is nothing which speaks against the referring of the two paroxysms of the southernmost Andes to the same great mountain-folding. Compared with *e.g.* the Alps, the Fuegian Cordillera was generally formed earlier, in so far that the optimum of folding (the Fuegian stage) took place when the Alpine orogenesis was still in an embryonic stage. The first signs of motion may be of more or less the same age (hercynic?).

One of the most important and interesting problems in the southernmost parts of the Andes is the tracing of the northerly continuation of the old Fuegian structures of Tierra del Fuego and the study of their rôle in the northern parts of Patagonia.

The formation of the Cordillera of Tierra del Fuego may be summarized as follows in accordance with the foregoing description:

1. The geosynclinal sediments, forming the dominating part of the central schists (Cordillera Darwin), are deposited (Devonian-Carbon).

2. The folding of the central schists sets in with the formation of the first geanticlines and intrusion of ophiolitic greenstones (Early Permian).

3. The eruption of the quartz-porphyries of Azopardo, Canal Beagle, etc., took place, and was followed by the deposition of the Yahgan and Buckland formations in the sea around the uplifted central parts of the Cordillera-geosyncline (Permo-Triassic).

4. In the peripheric zones of the folding-area, andesitic and basaltic eruption took place in connection with the beginning main folding. These rocks represent the oldest of the so-called propylites of South Navarino (Rio Douglas, Hoste, Isla Packsaddle). Contemporaneously graywackes and tuffitic sediments were deposited.

5. The main folding of the Central-Cordillera sets in (Fuegian Stage). The Cordillera schists are driven northward in »nappes» towards the foreland. The old »Flüsch»-deposits of the Buckland formation are overridden, and infolded with the central schists (Malm).

6. The Cordillera granites intrude and the orogenesis is gradually finished.

7. The Andean diorites intrude in the roots of the Cordillera. The corresponding effusive rocks penetrate the earth surface, as younger propylitic greenstones (Middle Jura).

8. The orogenesis has ceased and the erosion breaks down the mountain-range until the Andean diorites are exposed. The detrital sediments are deposited on the fore- and hinterland as »Flüsch»-sediments in the Jurassic Sea (Lias-Cretaceous, the Andean geosyncline according to GERTH, GROEBER etc.).

9. The orogenesis sets in again and the »Flüsch»-sediments are folded (Andean stage). The old Cordillera mainly acted as »Hinterland» and was not itself in any noteworthy degree influenced by the folding.

The later folding, during Late-Cretaceous time, was considerably less powerful than the main-folding during early Cretaceous and Jurassic times, and therefore the sediments were only slightly deformed. Traces of the volcanic activity in connection with this folding are not important on Tierra del Fuego. Some of the younger basaltic intrusions in the Cordillera belong without doubt to that stage, *e.g.* the basaltic rocks of Islas Carlos (the Strait of Magallanes) and probably also the well preserved basalt-beds etc. on the south part of Isla Hoste (Isla Packsaddle) and the Wollaston Islands.

Farther north, in South Patagonia, there is on the other hand a very important group of igneous rocks, which evidently have intruded in connection with the Late-Cretaceous folding. These are the laccolith granites and syenites of Cerro Balmaceda, Cerro Payne etc.

During the Cretaceous folding the older parts of the Cordillera evidently were rather passive, and acted as a resistant block. There are therefore very few signs of the young folding to be found in the rocks of the Main-Cordillera. This is particularly conspicuous with regard to the Andean diorites, which only in a few cases are deformed and altered. The lack of parallel-structure has been considered by several investigators (NORDENSKJÖLD, QUENSEL) as an evidence of young age — younger than the folded Cretaceous sediments —, a conclusion which, however, does not hold good.

There are, as a matter of fact, more traces of the orogenic movement in the Andean diorites than have been observed before. This influence is not visible in the inner parts of the igneous complex, but mainly along the north and east border, where the contact lies near the Cretaceous folding-zone. As we have seen, the diorites are in some degree deformed in all the small apophysic batholiths along Canal Beagle and more particularly at Isla Clar-

ence, which is the place where Andean dioritic rocks occur in the closest vicinity to the front part of the Central-Cordillera.

The most conspicuous trace of the younger folding in the older Cordillera rocks is the late brecciation of the Azopardo-porphyries (*cfr.* p. 73) which in this way finds a natural explanation.

During the later folding, the front part of the slate formation was probably in some degree overthrust over the Cretaceous »Flüsch»-sediments (Cap Froward, Canal Gabriel etc.).

After the conclusion of the folding, the Magallanean beds are deposited as extensive Molasse-deposits (Tertiary).

This assumption is of course in many points uncertain, the age-data in particular being only approximate, because in most cases no fossils which could facilitate determination have been found. Nevertheless, it gives at least a rough picture of the development of the Cordillera, and may be used as a base for further investigations and discussions.

Changes of level in the Cordillera during Post-Cretaceous time.

In the foregoing has been pointed out (p. 25) that the tangential movements of the Cordillera were finished at the termination of the Cretaceous time or at at the beginning of the Tertiary time. Disconformities between Upper Cretaceous and the Magellanean beds have been found both in South Patagonia and Tierra del Fuego. As far as is known at present, the Tertiary beds are nowhere influenced by the Cordillera folding. The slight folding in the Magellanean beds evidently depends on much later upliftings along the border of the mountain range. We here have to do with changes of level corresponding to the great vertical movements in the northern parts of Cordillera de los Andes, though the movements in the southernmost parts have by far not reached the tremendous proportions noticeable farther north.

The data available are, however, too scarce to allow of any definite conclusions regarding the proportions and the sequence of these movements. In the following only a few phenomena may be shortly summarized, as showing the importance of the post-Cretaceous epeirogenesis in the regions visited by the present author.

The most striking evidence of changes of level during late-Tertiary time, is of course the existence of marine Tertiary layers (Miocene to Pliocene) on Tierra del Fuego and South Patagonia several hundred metres above sea-level. The degree of uplifting of these layers seems to increase from south to

north. On Tierra del Fuego, at for instance Altos de Bucerone, the Tertiary beds lie about 400 m, at Magallanes on the north coast of the strait at 600 m (Miocene, Cerro Rio Grande). In the mountains north of Skyring water (Cordillera Vidal and Cerro de Penitente) marine Tertiary beds, probably Pliocene (?) covered with plateau basalts are found more than 1000 m above the sea. The almost peneplain-like plateau-formed crests of all these mountains prove, that the difference in height does not depend only on a different degree of denudation.

A plateau-level which evidently corresponds to the same pre-Miocene position of the base of erosion is found also at various places in the Cordillera of Tierra del Fuego, and has been mentioned from a number of localities in the foregoing description. A well developed peneplain surface is visible *i.a.* in the regions around the eastern parts of Canal Beagle (Isla Navarino, Peninsula Dumas etc.). Also Isla Dawson has a very even plateau-like crest. At the south part of Tierra del Fuego the plateau lies about 400 m above sea-level.

Also in the Central-Cordillera there are at several places terrace-like offsets in the cliff-wall at about 400 metres (*cfr.* for instance the photographs from Fjordo Finlandia p. 76 and Seno Almirantazgo p. 72).

It is at present impossible to decide if all these terraces and plateaus are of the same age — probably this is not the case — but there seems after all to be reason to believe that the land in Late-Tertiary time (Miocene-Pliocene) was on Tierra del Fuego 400 to 600 m lower than at present. The figure is, however, as yet merely approximate, we have almost no exact determinations of the plateau-heights, and the elevation of land may have been different in different parts of the country; probably it was, as already mentioned, greater northward than in the southernmost parts of the Cordillera.

We have also signs of negative changes of level during post-Cretaceous time. There is strong reason to interpret many of the big channels and fjords of the Cordillera as erosion-valleys which have sunk down under sea-level. Among valleys of this character the author above all wishes to mention Seno Almirantazgo, Fjordo De Agostini, Fjordo Martinez and possibly also Canal Beagle, above all its eastern part. Their direction and position is closely dependent on the grand tectonic structure of the Central-Cordillera (*cfr.* the stereogram p. 210) and they evidently have been established already in connection with the folding of the Cordillera. On the other hand they have been finished in comparatively late Tertiary time when the base of erosion was higher than now.

After the ending of the tangential movements of the cordillera-folding there was consequently a sinking of the earth crust to about 4—600 m below

the present niveau. (*cfr.* also the observations of HATCHER from the southern parts of Patagonia, 31). At this stage the plateaus named above were formed. During Pliocene and Pleistocene time the land was again lifted up over its present niveau, probably in connection with the big radial movements in the northern parts of Cordillera de los Andes. These phenomena are as yet very imperfectly studied and a more detailed investigation will certainly give a much more complicated picture of the movements of the earth crusts within the mountain-regions of Tierra del Fuego in Tertiary time, than shown by the few observations quoted in the foregoing. A great number of the stages of transgression and regression known from the Tertiary formations of Patagonia probably can be traced in the topographic forms of the Cordillera.

The interesting problems of the relation between the present topography of the Cordillera and the tectonic structure will be treated in another connection, and the author therefore confines himself to the foregoing hints. A definite solution of all these questions will of course be possible only when the tectonic conditions of the Cordillera north of the Strait of Magallanes, which now are still less known than those of Tierra del Fuego, have been more fully investigated.

LIST OF

	1	2	3	4	5	6	7	8
SiO_2	69.33	62,65	59.05	46.69	38.07	46.98	57.59	39.84
TiO_2	0.36	0.74	0.96	0.35	3.62	2.38	0.83	3.11
ZrO_2	0.01	0.03	0.01	n.d.	n.d.	n.d.	0.01	n.d.
Al_2O_3	17.05	16.13	16.64	18.51	17.17	16.60	18.33	17.32
Fe_2O_3	0.82	2.16	2.56	0.66	9.07	3.87	3.00	7.37
FeO	1.10	3.30	4.26	7.63	9.10	6.24	2.71	7.05
MnO	0.06	0.09	0.10	0.11	0.17	0.15	0.15	0.21
MgO	0.42	2.76	3.31	14.85	8.16	6.89	1.71	5.28
CaO	3.34	5.69	7.23	8.94	11.74	8.59	5.76	17.21
BaO	0.05	0.05	0.09	n.d.	n.d.	n.d.	0.07	n.d.
Na_2O	5.21	2.89	3.78	0.89	1.55	3.12	4.61	0.89
K_2O	1.66	3.11	1.77	0.52	0.34	2.09	4.62	0.58
P_2O_5	trace	0.15	0.33	non	trace	0.01	0.24	0.43
CO_2	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
S	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.07
F	n.d.	0.20	n.d.	n.d.	n.d.	n.d.	0.21	0.18
$H_2O +$	0.86	0.18	0.26	0.61	0.76	2.68	0.34	0.72
$H_2O -$	0.05	0.11	0.04	0.09	0.08	0.30	0.13	0.11
	100.32	100.24	100.38	99.85	99.83	99.90	100.31	100.37
$O \div F_2$		0.08					0.09	0.08
		100.16					100.22	100.29
G =	2.67	2.77	2.82	3.05	3.17	2.95	2.74	3.13

1. Granite. Isla Londonderry. S coast of Tierra del Fuego.
2. Augite-hornblende-biotite diorite. Isla Nelson.
3. Augite-biotite diorite. Isla Duntze, Canal Cockburn.
4. Olivine gabbro. Isla Duntze, Canal Cockburn.
5. Magnetite-hornblende gabbro. Isla Duntze, Canal Cockburn.
6. Spessartite. Isla Duntze, Canal Cockburn.
7. Monzonite. Rio Douglas, S Isla Navarino.
8. Diopside gabbro. Rio Douglas, S Isla Navarino.
9. Gneiss. Ventisquero Jendegaia, Canal Beagle.
10. Epidote-biotite diorite. Ventisquero Italia, Canal Beagle.

ANALYSES.

9	10	11	12	13	14	15	16	
75.41	59.96	53.75	48.06	57.60	48.63	79.19	63.59	SiO_2
0.25	2.48	2.83	1.21	1.92	2.34	non	trace	TiO_2
0.03	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	ZrO_2
13.21	17.25	18.60	17.61	15.64	14.85	9.88	18.63	Al_2O_3
0.80	1.87	2.04	2.49	0.50	1.91	0.21	0.56	Fe_2O_3
1.06	3.31	6.97	6.02	6.61	9.47	0.63	1.62	FeO
0.02	0.12	0.18	0.11	0.19	0.12	n.d.	n.d.	MnO
0.07	2.14	2.30	4.31	3.69	7.93	0.55	4.98	MgO
1.51	6.47	6.98	9.04	4.87	7.20	non	2.14	CaO
0.06	n.d.	n.d.	0.03	n.d.	n.d.	n.d.	n.d.	BaO
3.57	3.68	4.06	2.98	4.24	2.98	0.66	1.78	Na_2O
4.11	2.06	1.32	1.13	0.21	0.30	7.68	2.07	K_2O
trace	0.22	trace	trace	trace	0.01	n.d.	n.d.	P_2O_5
n.d.	n.d.	0.49	5.36	2.01	0.18	0.64	0.65	CO_2
n.d.	n.d.	n.d.	n.d.	0.11	0.21	n.d.	n.d.	S
n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	F
0.11	0.75	0.76	1.22	2.61	4.09	0.54	4.24	$H_2O +$
0.03	0.05	0.07	0.77	0.06	0.21	0.03	0.14	$H_2O -$
100.24	100.36	100.35	100.34	100.26	100.43	100.01	100.20	
								$O - F_2$
0.66	2.79	2.97	2.74	2.81	2.92			

11. Mylonitic diorite. Valle Desillusion, N of Lapataia, Canal Beagle.
12. Melaphyre, Islas Carlos, Strait of Magallanes.
13. Metabasalt. Bahia Tres Brazos, Isla Gordon.
14. Ophiolitic greenstone. N of Monte Olivia, S Tierra del Fuego. L. Lokka anal. 1930.
15. Black felsite porphyry, Bahia Rodriguez, Skyring Water, Patagonia, M. Dittrich anal. (Quensel 45)
16. Porphyroid (altered). Bahia Rodriguez, Skyring Water, Patagonia, M. Dittrich anal. (Quensel 45).

LIST OF LOCALITIES.

Fig. 60. Map showing the localities treated in the paper.

LIST OF PICTURES, PROFILES AND MAPS.

LITERATURE REFERRED TO IN THE TEXT.

1. AGOSTINI, ALBERTO M. DE: Zehn Jahre im Feuerland. Leipzig 1924. 308 p., 118 fig. 2 Panoramas and 3 maps.
2. ANDERSSON, J. G.: Geological fragments from Tierra del Fuego. Bull. Geol. Inst. Univ. Upsala VIII, 1907, 169—183 p., 3 pl., 6 fig. in the text.
3. ANUARIO HIDROGRAFICO: Santiago de Chile. Vol. 26, 1907.
4. ARGAND, EMILE: L'Exploration géologique des Alpes Pennines Centrales. Bull. des lab. de géologie, etc. de l'Université de Lausanne (Suisse). No. 14. Lausanne 1909. 64 p., 3 fig., 1 pl.
5. —»— La tectonique de l'Asie. Congr. Géol. Intern. XIIIe Session, 1922. 171—372 p., 27 fig.
6. BACKLUND, HELGE G.: Der Magmatische Anteil der Cordillera von Süd-Mendoza. Acta Acad. Aboensis Math. et Phys., 11, 1923. 298 p., 5 pl., 1 map. 22 fig. in the text.
7. —»— Magmatic Activity and Mountain Folding in the Andes of the South Mendoza. Geological Magazine. Vol. LXIII. No. 747, 410—422 p., 10 fig. in the text.
8. BAECKSTRÖM, OLOF: Petrographische Beschreibung einiger Basalte von Patagonien, Westantarktis und den Süd-Sandwich-Inseln. Bull. of Geol. Inst. of Univ. Upsala. Vol. XII, 1, 1914—15. 115—182 p.
9. BEGER, P. J.-NIGGLI, P.: Gesteins- und Mineralprovinzen. Bd. I. Einführung. Berlin 1923. 602 p., 202 fig.
10. BECKER, G. F.: Finite homogeneous strain, flow and rupture of rocks. Bull. of the Geol. Soc. of America, 4, 1893.
11. BONARELLI, GUIDO: Tierra del Fuego y sus Turberas. Anal. del Ministerio de Agricultura de la Nacion. Secc. Geol. Min. y Mineria. Tomo XII. Nom. 3, 1917. 119 p., 3 maps, 3 fig. in the text.
12. BOWEN, N. L.: The Evolution of Igneous Rocks. Princeton 1928. 332 p., 82 fig.
13. BRÜGGEN, E.: Informe sobre las esploraciones geologicas de la region carbonifera del Sud de Chile. An. Soc. Nac. de Mineria 1913, 15—19 p., Santiago de Chile.
14. BRÖGGER, W. C.: Die Eruptionsfolge der triadischen Eruptiv-gesteine bei Predazzo in Süd-Tirol. Videnskabsselskabets Skrifter. Kristiania. Mth. nat. kl., 1895. No. 7. 183 p., 18 fig.
15. BUDDINGTON, A. F.: The Adirondack Magmatic Stem. The Journal of Geology. Vol. XXXIX. No. 3. 240—263 p., 3 fig. in the text.
16. BURRI, CONRAD (Julius Romberg): Neue Beiträge zur Petrographie von Predazzo und Monzoni. N. Jahrb. f. Min. etc. Bd. LVIII. Abt. A, 1928. 109—140 p., 1 pl., 7 fig. in tex.

17. DARWIN, CH.: Geological notes on South America. London 1846. 380 p.
18. DOELLO-HURADO, M.: Note preliminaire sur les resultats géologiques de l'expédition de l'université de Buenos Aires à la Terre de Feu (1921). Congrès international. Comptes Rendus de la XIII-me Session en Belgique 1922. 3-me fasc. Liège 1926. 1519—1520 p.
19. ESKOLA, P.: The mineral facies of rocks. Norsk Geol. Tidskr. 6, 1921. 143—194 p., 7 fig.
20. —»— Om Mineralfacies. Geol. Fören. Förh. 1929, 51. 157—172 p.
21. FELSCH, J.: Reconocim. geol. de los terrenos petrolif. de Magallanes del Sur. Primera Parte. Boll. Nac. Min.; Mayo—Junio, 1916. Santiago de Chile.
22. —»— Reconocim. geol. de los alreded. de Punta Arenas y de parte N.O. de la Tierra del Fuego. Bolet. Inspecc. geogr. y Minas. LV, 1912. Santiago de Chile.
23. GALLOIS, L.: Les Andes de Patagonie. Ann. de Geogr. 10e année (No. 51), 1901. 232—259 p.
24. GERTH, H.: Die Bedeutung der geologischen Erforschung des Südrandes der Puna de Atacama für die Geschichte der Anden und der Gebirgsbildung im Allgemeinen. Geol. Rundschau XII, 1922. 320—340 p.
25. —»— Ausbildung und Fauna der mesozoischen Ablagerungen in der andinen Geocynclinale im Bereich der argentischen Cordillera. Geol. Rundschau. XIV, 1923. 90—93 p.
26. GOLDSCHLAG, M.: Über die optischen Eigenschaften der Epidote. Tscherm. min. petr. Mitt. 34, 1917. 23—60 p., 7 fig.
27. GROEBER, P.: Estratigrafia del Dogger. Dirección de Minas. Bol. 18. Buenos Aires 1918. 76 p.
28. GRUBENMANN, U.: Über einige schweizerische Glaucophangesteine. Rosenbusch-Festschrift 1906.
29. GOLDSCHMIDT, V. M.: Stammestypen der Eruptivgesteine. Skrifter utg. av Videnskapsselskapet i Kristiania. I. Mat. Nat. Kl. 1922, 10. 12 p., 4 fig.
30. HALLE, G. TH.: Some mesoz. Plant-bearing Deposits in Patag. and Tierra del Fuego and their floras. Kungl. svensk. Vetensk. Akad. Hand. Bd. 51. No. 3. Upsala and Stockh. 1913. 58 p., 5 pl., 4 text-fig.
31. HATCHER, J. B.: On the geology of South Patagonia. Americ. Journ. of Sc. 1897. T. 4. 327—54 p., 11 text-fig.
HAUTHAL (*cfr.* Wilckens).
32. HYADES: Mission Scientifique du Cap Horn. 1882—1883. T. IV; Geologie. Paris 1887. 242 p., 30 pl.
33. IHERING, H. V.: Nouv. rech. sur la format. magell. Anal. Muc. Nac. de Buenos Aires. Ser. III. T. XII, 1909, 27—43 p.
34. JAWORSKI, E.: Die Trias, Lias und Doggerfauna der andinen Geosynklinale und ihre Verwandschaftlichen Beziehungen. Geol. Rundschau 1923, 14. 83—89 p.
35. KEIDEL, H.: Ueber das Alter, die Verbreitung und die gegenseitigen Beziehungen der verschiedenen tektonischen Strukturen in den argentinischen Gebirgen. C.R. Cong. geol. inter. XII, 1913. p. 671.
36. KING, P. P. and FIZ-ROY: Narrat. of the Surveying voyage of H.M. ships »Adventure» and »Beagle» between the years 1826—1836 describing their examination of the southern shores of South America. London 1839. 3 vol.

37. KRANCK, E. H.: Sur la tectonique de la Cordillère de la Terre de Feu. Extrait du C.R.S. de la Société Géologique de France. No. 7, 1930. 66—67 p.

38. —»— Sur le profil longitudinal de la Cordillère de la Terre de Feu. Extrait du C.R.S. de la Société Géologique de France. No. 10, 1930. 102—103 p.

39. DE LAPPARENT, JACQUES: Roches à radiolaires du dévonien de la vallée de la Brouche. Bulletin du la Carte Géologique d'Alsace et de Lorraine. Tome 1, fasc. 2, 1923. 46—64 p., 6 text-fig., 6 pl.

40. NORDENSKJÖLD, O.: Geological Map of the Magellan Territories with Explanatory Notes. Svenska expeditionen till Magellansländerna. Bd. 1. No. 3. 81—85 p., 1 map.

41. —»— Die kristallinen Gesteine der Magellansländer. Svenska expeditionen till Magellansländerna. Bd. 1. No. 6. 175—240 p., 1 pl., 4 text-fig.

42. —»— Über die posttertiären Ablagerungen der Magellansländer nebst einer kurzen Übersicht ihrer tertiären Gebilde. Svenska expeditionen till Magellansländerna. Bd. 1. No. 2. 1% —76 p., 6 pl., 10 text-fig.

43. NOVARESE, V.: Nomenclatura e sistematica delle roccie verdi n. alpi occidentali. Boll. Commit. geol. Ital. 1895. 164—181 p.

44. D'ORBIGNY, A.: Voyage dans l'Amerique meridional. 3-me part; Geologie. Paris 1842.

45. QUENSEL, P.: Geologisch-Petrographische Studien in der Patagonischen Cordillera. Bull. of the Geol. Instit. of Upsala. Vol. II, 1911, 1. 114 p., 4 pl., 26 text-fig., 1 map.

46. —»— Beitrag zur Geologie der patagonischen Cordillera. Geol. Rundschau I, 1910. 297—302 p.

47. —»— Die Quarzporphyr- und Porphyroidformation in Südpatagonien und Feuerland. Bull. Geol. Inst. Upsala, II, 1912. 1—40 p., 12 text-fig.

48. RIGAL, REMIGIO: El Liasico en el Cordillera del Espinacito (San Juan). Direc. Gen. de Minas, Geol. e Hidr. Buenos Aires. Pbl. No. 74, 1930. 4 p.

49. ROMBERG, JULIUS: Über die chemische Zusammensetzung der Eruptivgesteine in den Gebieten von Predazzo und Monzoni. Abh. Königl. Preuss. Akad. Wiss. 1904. 135 p., 1. table (*cfr.* also Burri).

50. SANDER, BRUNO: Gefügekunde. Wien 1930. 352 p., 155 text-fig., 245 diagram.

51. SKOTTSBERG, C.: The Swedish Magallanic Expedition, 1907—1909: Preliminary report. The Geographical Journal, oct. 1909. 409—421 p.

52. —»— Die Vegetationsverhältnisse der Cordillera de los Andes S. von 41° S. Br, Kungl. Svenska Vet. Ak. Handlingar. Bd. 56. 1916. 366 p. 23 Pl. 24 text-fig.

53. STAUB, RUDOLF: Der Bewegungsmechanismus der Erde. Berlin 1928. 270 p., 1 map, 44 text-fig.

54. STEFFEN, H.: Westpatagonien I—II. Berlin 1919. 1028 p., 32 pl., 67 fig., 8 maps.

55. STEINMANN, G.: Reisenotizen aus Patagonien. Neues Jahrb. f. Min. etc. 1883, II. 255—58 p.

56. —»— Geologische Beobachtungen in den Alpen. II. Berichte der Naturf. Ges. Freiburg. Bd. 16, 1906. 49 p.

57. —»— -WILCKENS, O.: Vorläufiger Bericht über die Bearbeitung der von der Schwedischen Expedition nach den Magellansländern gesammelten marinen Fossilien. Wiss. Ergebn. d. Schwed. Exp. n.d. Magellansländern. Bd. 1, 1907. 249—252 p.

58. Steinmann-Wilckens, O.: Kreide- und Tertiärfossilen aus den Magellanesländern, gesammelt von der Schwedischen Expedition 1895—1897. Arkiv f. Zoologi der Schwed. Ak. d. Wiss. Bd. 4. Nr. 6, 1907. 118 p., 7 pl., 3 text-fig.

59. —»— Das Alter der Schieferformation im Feuerlande. Centralbl. f. Min. 1908, 193—195 p.

60. —»— Gebirgsbildung und Massengesteine in der Kordillera Südamerikas. Geol. Rundschau 1910. 13—16 p.

61. Tschopp, Hermann: Die Casannaschiefer des oberen Val de Bagnes (Wallis). Eclogae Helvetiae. Vol. XVIII, 1923. 77—206 p., 2 pl., 1 text-fig.

62. Vogt, Th.: Sulitelmafeltets Geologi og Petrologi. Norges geol. Undersökning 121, 1927. 40 Pl., 104 text-fig. 560 p.

63. Weg, Otto: Die zwischengebirgische Prasinitscholle bei Hainichen-Bebersdorf. Abh. d. Sächs. Geol. Landesamts. Heft 11. Leipzig 1931. 140 p., 16 pl., 19 text-fig.

64. Windhausen, A.: Ein Blick auf Schichtenfolge und Gebirgsbau in südlichen Patagonien. Geol. Rundschau 12, 1921. 109—137 p., 1 pl.

65. —»— Geologia argentina. Secunda parte. Buenos Aires 1931. 645 p., 1 map, 58 pl., 214 text-fig.

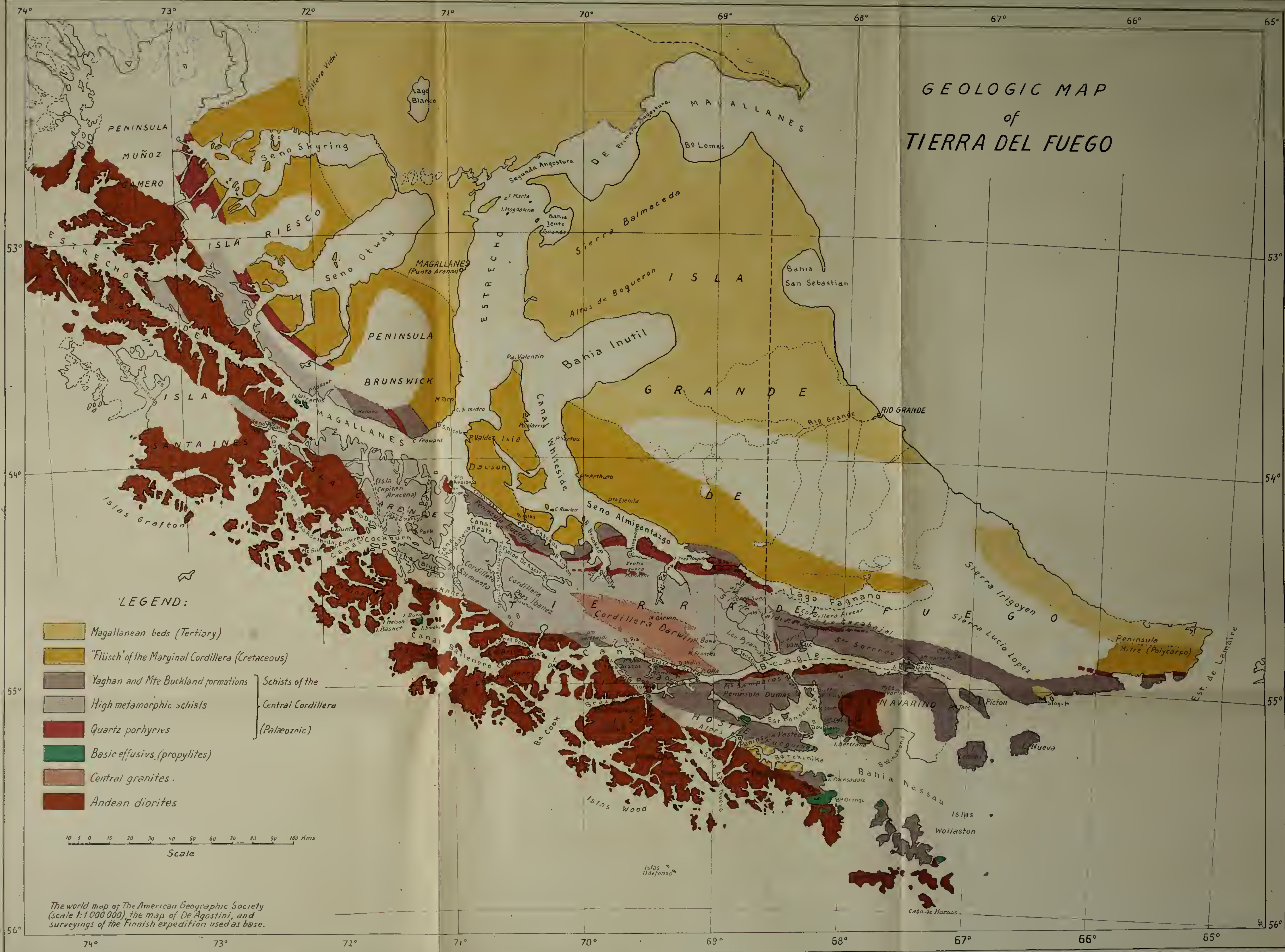
66. —»— Bau und Bild Patagoniens. Zeitschr. der Gesellschft. f. Erdkunde zu Berlin. Nr. 1/2, 1932. 18—38 p., 8 text-fig., 2 pl.

67. Wilckens, O.: Erläuterungen zu Hauthals Geolog. Skizze des Gebietes zwischen den Lago Argentino und dem Seno de la Ultima Esperanza (Südpatagonien). Berichte der Naturf. Ges. Freiburg f.B. Bd. 15. 22 p., 1 map.

68. —»— Ueber Fossilien der oberen Kreide Südpatagoniens. Centralbl. f. Min., etc. 1904. 597—599 p.

CORRECTION

On the map the name Y a h g a n erroneously is spelt Yaghan.



Suomalaisen Kirjallisuuden Seuran Kivipaino, Helsinki

ACTA GEOGRAPHICA
4

1 Map; 33 Plates; 33 Figures in the Text; Text 242 Pages.